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MEET THE GUY that ELIMINATED HIS TEAM'S
MANUFACTURING VARIABILITY ISSUES.

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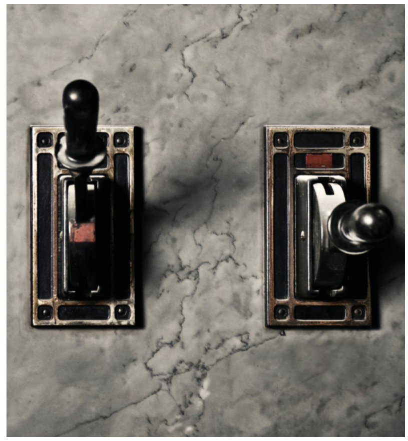

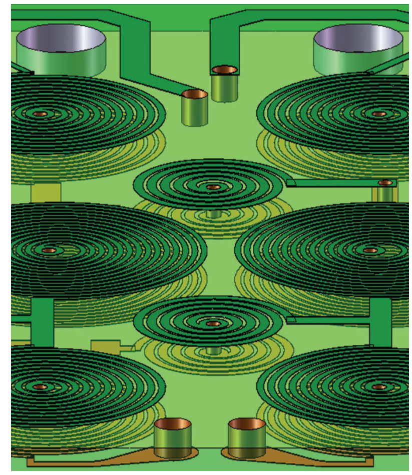

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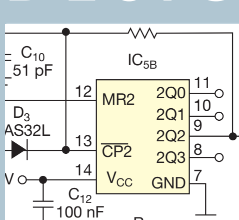

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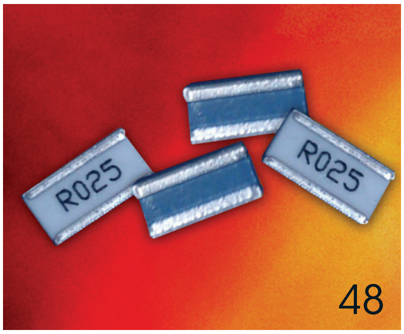

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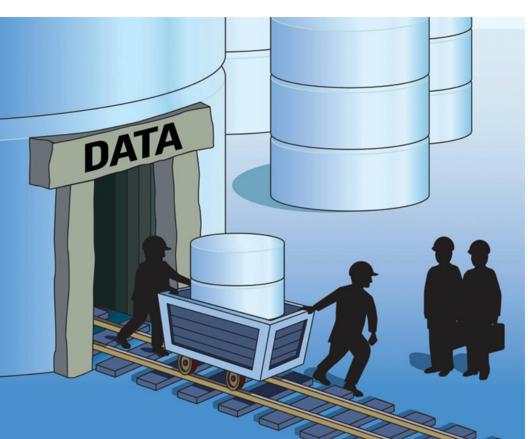
BY RON WILSON, EXECUTIVE EDITOR

Is workflow automation the next frontier for EDA?

Dassault Systemes Enovia, IBM Software Group, and Methodics stood out from the crowd on the show floor at the DAC (Design Automation Conference) this year—not for their huge booths or the novelty of their products, but simply by being dramatically different from the mainstream of EDA thinking. Each company employs PLM (product-life-cycle management), which plays a growing role in enterprise operations. As the scale of IC-design efforts increases, PLM probably lies in the future for many chip-design teams.

To the IC-design profession, PLM has some specific meanings, one of which is simply version control. A second aspect is workflow management: tracking data sets, tasks, and outcomes through an organization as the project progresses. Combine these meanings and season them with message tracking and conferencing, and you get an inter-team collaboration platform.

Also crucial to PLM is the notion of traceability. Every object in the design, from a line of C++ to a signal to a field-service call, should be traceable back to the design requirements that justified it.



Traceability also refers to the documentation of every step in design, verification, production, and test. As you can imagine, these are huge databases here; this job is not for one person with Excel.

So far, all of these tasks are familiar. Chip-design teams have been finding ways to perform version control and have for years taken stabs at a semiautomated workflow. Aerospace designers have lived with traceability and documentation mandates, such as DO-178B, at least in the software world. Some vendors are also familiar. A major component of Dassault's product traces its heritage to Synchronicity, which years ago tried to sell collaboration tools to chip designers. Similarly, parts of the industry know and use the Methodics project IP (intellectual-property)-control tool.

Two points are less familiar. First, many point tools are showing signs of becoming a comprehensive platform. Such a platform would support all aspects of the product life cycle and offer unprecedented opportunities for data mining. Second, separate from this trend but enormously enriching to it, design teams are beginning to attach quantitative figures of merit to the outcomes of design-and-verification tasks.

According to Indavong Vongsavady, projects director at STMicroelectronics, the importance of PLM tools may lie in their ability to methodically collect design-and-verification metrics to support decisions. "Most tools produce metrics, but not all engineers interpret them the same way," he says. "There are different ways of measuring quality of results."

Some obvious measures, such as the distribution of timing slack in block or power-consumption estimates, define design quality. Less obvious metrics include the degree of manipulation or the number of buffers a netlist requires to close timing, for example. Experience tells a design manager how a certain structure should behave, allowing the manager to normalize such metrics and estimate whether a block requires intervention. PLM tools can play a key role in capturing, organizing, and preserving that experience and in mining

Product-life-cycle management probably lies in the future for many chip-design teams.

nuggets that might be less obvious on the surface. You can make a similar case for verification metrics.

The sheer scale of next-generation designs, comprising huge gate counts, IP from a wide array of sources, and massive software efforts, will require some sort of project-management automation. PLM tools, although they may seem foreign to the EDA world, are likely the best candidates for this task. In applying PLM to electronic-systems design, you may find that the data-mining capabilities of the tools add a new dimension to productivity improvement. EDN

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Rohde & Schwarz enters the time domain

The Rohde & Schwarz test-and-measurement division is entering the time-domain-analysis business with families of oscilloscopes that offer bandwidths to 2 GHz. Speaking on June 28, Michael Vohrer, then-R&S chief executive officer, said the time-domain initiative represents an attempt of the privately held company to push into new markets and expand market share in traditional markets. Vohrer estimates that the scope market is worth $1 billion and says that, with a highly diversified customer base, it represents lower volatility than that of other segments.

Roland Steffen, head of the R&S test-and-measurement division, says the new offerings will complement the under-500-MHz offerings from the Hameg subsidiary, which R&S acquired five years ago. Initial models in the new line offer top bandwidths of 500 MHz and 2 GHz, which, he adds, are the bandwidths having the largest share of market volume.

According to Josef Wolf, head of the company's spectrum and network analyzer, EMC (electromagnetic-compatibility) test, and oscilloscope subdivision, the scope-development effort focuses on high-level integration of analog-, digital-, and mixed-signal subsystems. A key goal was a low-noise analog front end, which R&S achieves using a single-core, SiGe (silicon-germanium), 10-GHz ADC with an ENOB (effective number of bits) better than seven. A 90-nm ASIC with 15 million gates provides hardware implementation of digital-signal-processing functions, enabling the analysis of 1 million waveforms per second.

The 2-GHz top-of-the-line RTO models employ a purely digital trigger system that eliminates the alignment errors that can occur with software-compensation schemes in conjunction with separate analog triggers, specifying RTO trigger jitter in femtoseconds rather than picoseconds. The digital trigger eliminates rearm times associated with analog triggers, which can mask events of interest that occur shortly after an analog trigger. The RTO provides as much as 20 times less blind time than competitors to identify intermittent problems.

RTO models are available in two- and four-channel models with bandwidths of 1 and 2 GHz. The sampling rate is 10G samples/sec. They support a Windows-driven touchscreen user interface. The new RTM models offer 500-MHz bandwidth and 5G-sample/sec sampling. They boot within 7 seconds to help provide fast measurement results. Prices for RTM instruments start at €5000; prices for RTO instruments start at €12,000.**—by Rick Nelson**

▷**Rohde & Schwarz**, www.rohde-schwarz.com.

RTO models are available in two- and four-channel models with bandwidths of 1 and 2 GHz. The sampling rate is 10G samples/sec. The instruments support a Windows-driven touchscreen user interface.

FEEDBACK LOOP

"Your black-market pills will either barely work … , or they'll be borderline overdose … , with nothing in between."

—*EDN* reader AM Anderson, in *EDN*'s Talkback section, at http://bit.ly/cTm8ym. Add your comments.

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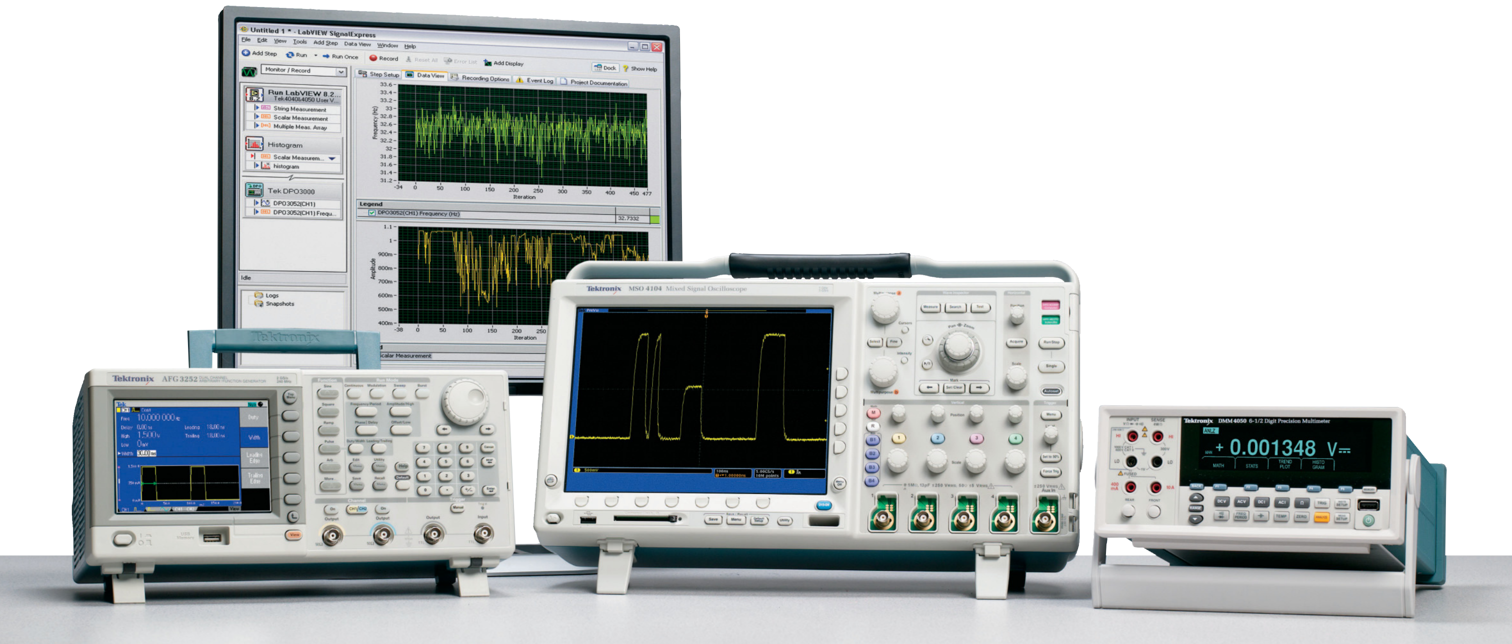

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Pseudogap-phase research could be key to room-temperature superconductivity

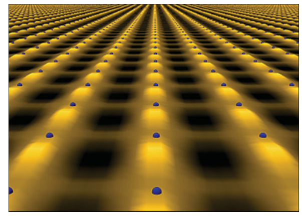
New research may lead to a better understanding of the "pseudogap" phase. Scientists have hypothesized that this gap is a key hurdle to achieving room-temperature superconductivity. The pseudogap phase is nonsuperconducting, and researchers have observed it at a temperature higher than the superconducting phase.

To date, scientists have been unable to increase to room temperature the temperature at which copper-oxide superconductors carry current with no resistance. They believe that it is possible that room-temperature superconductivity can operate without energy loss and without the use of coolants, such as liquid helium or nitrogen, which are currently necessary and which hinder the superconductors' use in everyday applications.

An article in *Nature* describes the research, detailing a newly discovered fundamental difference in how electrons behave at the two oxygen-atom sites within each copper-oxide unit, which appears to be a property of the nonsuperconducting pseudogap phase (**Reference 1**).

"Many people consider the disappearance of superconductivity that occurs when the pseudogap phase emerges as an indication that the pseudogap is the killer of room-temperature superconductivity in the copper oxides," says study leader Séamus Davis, director of the Center for Emergent Superconductivity at the US Department of Energy's Brookhaven National Laboratory (www.bnl.gov) and the JD White Distinguished Professor of Physical Sciences at Cornell University (www.cornell.edu). "Detecting a difference in electron behavior at the two oxygen sites within each copper-oxide unit at the pseudogap energy may be a very significant step toward identifying exactly what the pseudogap state is and how it affects superconductivity."

A group of researchers used spectroscopic imaging-scanning-tunneling microscopy to measure the relative ease at which electrons could jump from the surface at each copper and oxygen site to the tip of the microscope needle. The scientists found that the number of electrons across the entire copper-oxide crystal that could "tunnel" to the microscope tip differed depending on the position of the oxygen atom relative to the copper atom.



This pattern shows the tunneling potential of electrons on oxygen atoms "north" and "east" of each copper atom (embedded in the pattern) in the copper-oxide layer of a superconductor in the pseudogap phase. On oxygen atoms north of each copper atom, the tunneling potential is strong, as the brightness of the yellow patches forming lines in the north-south direction indicates. On oxygen atoms east of each copper atom, the tunneling potential is weaker, as the less intense yellow lines in the east-west direction indicate. This apparent broken symmetry may help scientists understand the pseudogap phase of copper-oxide superconductors (courtesy Brookhaven National Lab).

The scientists will pursue their pseudogap research by looking for a similar broken symmetry in other copper-oxide superconductors. They will then try to determine how the directional asymmetry in electronic behavior affects the ability of electrons to flow through the system, how that directional dependence might inhibit superconductivity, and how to overcome this inhibition at temperatures warm enough to make high-temperature superconducting technologies practical.

The team included researchers from Binghamton University, Cornell, Brookhaven National Lab, the University of Tokyo, the Korea Advanced Institute of Science and Technology, Japan's RIKEN (Rikagaku Kenkyusho), and Japan's Institute of Advanced Industrial Science and Technology. The scientists believe that the research could be key in meeting future energy needs.

"The ultimate goal is to discover or create materials that can act as superconductors, to carry electric current with no energy loss, at room temperature," Davis says. "Developing superconductors that operate without the need for coolants would be transformational. Such materials would greatly improve the efficiency of energy-distribution systems, saving enormous amounts of money and updating the electrical grid to meet the needs of the 21st century."

—by Suzanne Deffree

▷**Center for Emergent Superconductivity**, www.bnl.gov/energy.ces.

REFERENCE

1. Lawler, MJ, K Fujita, Jhinhwan Lee, AR Schmidt, Y Kohsaka, Chung Koo Kim, H Eisaki, S Uchida, JC Davis, JP Sethna, and Eun-Ah Kim, "Intra-unit-cell electronic nematicity of the high TC copper-oxide pseudogap states," *Nature*, July 15, 2010, pg 347, http://bit.ly/dC6BVX.

DILBERT By Scott Adams

Rarely Asked Questions

Strange stories from the call logs of Analog Devices

Contributing Writer John Ardizzoni is a Senior Application Engineer at Analog Devices in the High Speed Linear group. John joined Analog Devices in 2002, he received his BSEE from Merrimack College in N. Andover, MA and has over 30 years experience in the electronics industry.

Is Your Amplifier Disabled, or is it Merely Sleeping?

Q: What's the difference between, power-down, shutdown, standby, sleep mode or disable?

A. While all these functions may sound similar, they can have very different meanings depending on the specific amplifier and the manufacturer.

We use the terms *power-down* and *shutdown* to represent the state of an amplifier when the quiescent supply current is lowered from its *normal* operating level. The supply current is typically throttled back by reducing the current in the amplifier's internal bias circuitry. For example, an amplifier that draws milliamps of quiescent current in normal mode may draw only microamps or even nanoamps in power-down mode. The amplifier's output voltage is undefined in both power-down and shutdown modes.

We use the term *disable* to represent the state of an amplifier whose quiescent supply current is reduced from the normal *on* state of the amplifier, but with the additional feature that the output goes to a high-impedance state when the device is put into disable mode. This extremely useful condition provides high input-to-output isolation, and enables outputs to be multiplexed by wire or'ing them together.

Read the data sheet carefully. For a simple power-down function, the specification table may contain a couple of lines that discuss the power parameters, or there may be a plot of normal vs. power-down supply current. There may also be a plot of the power-down current over temperature. For a disable function (high-impedance state), you can expect the same specification table references, but you may also find an output impedance vs. frequency plot—as the high output impedance is not constant over frequency—or a circuit example featuring the high-impedance capability of the device in a multiplexed application. Also be careful to note the *power-down* threshold voltages. Op amps do not have ground pins, so most power-down circuits are internally referenced to one of the supply rails. The switching levels may not be compatible with conventional logic signals and may thus require some type of level translation.

Not all manufacturers use the same naming convention; what one manufacturer calls disable another may call shutdown, so you should consult the manufacturer's data sheet for their definition of power-down, shutdown, or disable.

To Learn More About Power-Down Functions
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VOICES

Bill Watkins and Mark McClear: ensuring LED-light quality

The US EPA (Environmental Protection Agency, www.epa.gov) is creating an Energy Star performance rating for lighting luminaires. The proposed "technology-blind" criteria lump CFLs (compact fluorescent lighting), LED-based SSL (solid-state lighting), and halogen lighting into the Energy Star draft document "Energy Star Program Requirements for Luminaires" (http://bit.ly/aJbTSn). The document goes beyond simply specifying light efficacy to specify quality metrics, such as color, color metrics, lumen maintenance, and lifetime. Two representatives of major LED manufacturers—Bill Watkins, chief executive officer of Bridgelux, and Mark McClear, director of application engineering and new-business development at Cree—have strongly differing opinions on whether the proposed ratings are helpful or harmful to the fledgling SSL industry. Despite their differences of opinion on how best to ensure LED-lighting quality and lifetime, Watkins and McClear agree that Energy Star should have separate guidelines for LED lights. "[The current draft] gives a pass to CFLs on lifetime [at less than 8000 hours] but holds LED lights to 35,000 hours," says Watkins. "It unfairly protects the [CFL] bulb guys."

Why does an energy-efficiency program, such as Energy Star, stipulate quality metrics?

A **Bill Watkins** It doesn't belong there. ... It's a question of how you want to police lifetime and reliability. LEDs are about innovation. [With the proposed Energy Star guidelines,] every time we come up with a new die or epitaxy, we have to go through a nine-month test. So, one of two things will happen: Either innovation stops because people have to wait nine months to change things so that everything slows to a snail's pace, or people cheat on the test or fudge the data.

Mark McClear These quality metrics are vital. The EPA is saying that efficacy is important. If the color is bad, it flickers, you can't dim it, or it doesn't last very long, or experiences color changes during its lifetime, then it doesn't matter how much energy it saves because nobody will use it. I think the DOE [Department of Energy, www.energy.gov] has wisely reached a balance between efficacy and quality because the agency wants to ensure the adoption of the technology and realize the energy benefits.

Is a warranty a better alternative to making quality metrics, such as lifetime, a part of the Energy Star spec?

Watkins

A **BW** A warranty is the best way. … With this test requirement, it will actually reduce energy saving because of the [additional] time needed to bring new technology to market and potentially drive up costs, as well. It's not up to the government to decide [product lifetime]; it's not up to us as the source manufacturer to decide.

It's up to the end users to decide what they want. If a standard limits your choices, it limits your options. If we put on the box "this thing will go 10,000 hours, and we'll give you a three-year warranty, and we're public and honest about it," what else matters?

MM What good is a five-year warranty from a company that's only been around for a year? I'd get a little nervous about that [scenario].

Also, you look at the balance sheet of these start-up [LED-lighting] companies. If they put products out on the street and they don't have the financial capabilities to warranty them, the warranty isn't worth the paper it's printed on.

I think the overarching theme here is that the DOE has chosen both energy efficiency and quality to ensure that the energy-efficiency gains are realized.

If they leave quality to start-up and import companies, you could get bad quality and turn off an entire generation from using SSL.

McClear

Energy Star is a voluntary program. Do companies have a choice whether to comply?

A **BW** A lot of lighting manufacturers want the rating to get into certain retail channels or because it's required for rebates. Also, many commercial accounts require that their purchases meet Energy Star requirements.

MM If you walked through [last May's] Lightfair [lighting-industry trade show], 95% of the luminaires you saw were not Energy Star-compliant, and people are buying them without it.

What about Energy Star in the broader world arena?

A **BW** Asia and Europe don't have lifetime as part of their energy-efficiency specifications. LED innovation will happen in countries where they don't have these sorts of tests. You can't protect the consumer from everything. We need to be able to innovate in America at the same rate as the rest of the world.

MM There is no comparable program in the world. But lighting manufacturers can always enter the market on a level playing field with international competitors and then, nine months later, when you pass the tests and get the documentation, put the Energy Star on the luminaire.

—interview conducted and edited by Margery Conner

BY BONNIE BAKER

Beyond timing, accuracy, and repeatability

When you decide which converter will work best for your application, you may first think about the speed, accuracy, and repeatability of your perspective system. OK, but let's try to get beyond the obvious. Your e-mails over the last few months related to this topic are insightful. Thank you very much for taking the time to send your ideas my way.

Harvey Wiggins sent an e-mail discussing the difficulty behind trying to make a group of delta-sigma converters operate simultaneously. "Our application calls for more than 200 simultaneous channels at low power," he writes. "We felt as though 24 bits would have enough dynamic range to use a fixed gain stage. Upon further investigation, it proved difficult to design [these devices] into our system because [delta-sigma] ADCs have to run continuously, with a continuous clock to operate the [internal]-filter stages. It would have been a tough job to start up 200-plus ADCs simultaneously across four or more boards. The synchronization of the startup with a system sample clock is tricky because the clock for the delta-sigma converters is not necessarily a nice multiple of the desired sample period. There usually is a defined clock-synchronization protocol, but all the edges have to line up exactly across multiple converters and boards."

Wiggins took the easier and lower-power route of going to 18-bit SAR converters, even though they are more expensive.

"For time-domain signal acquisition, which requires edge preservation, I would choose the PGA-SAR [programmable-gain-amplifier successive-approximation-register ADC]," writes Larry Bodnar. "For frequency-domain signals, such as music audio, sigma delta would be the obvious choice."

These thoughts are astute. The SAR-ADC system takes a "snapshot" of the input entity you are monitoring. The delta-sigma converter repeatedly samples the input entity, combining these samples through a digital filter for a final conglomerate-output digital value. This digital value represents an input signal over time.

The delta-sigma ADC is a viable alternative to the traditional SAR-ADC system.

Al Welch believes that delta-sigma converters are better. "I have used them for years," he writes. "I have not used external gain in a long time. I worry about resistor drift when you have external gain resistors. I would guess that even those with programmable gain are going to have some limitations due to resistor drifts. I know we can find delta-sigma converters that are pretty good in the low-ppm [parts-per-million] range. Conversion speeds have risen with delta-sigma converters, as well. Of course, if you need high sample rate you may be looking at a SAR, but not with the accuracy of a delta sigma."

Welch is enthusiastic about delta-sigma converters; however, the delta-sigma units have problems meeting all of the PGA-SAR performance levels. Welch questions the stability of external gain resistors—and that concern may be well-founded—but an integrated solution has matched on-chip gain resistors.

What about other issues, such as cost, reliability, and power for battery-powered applications? Although PGA-SAR systems have multiple chips, they generally cost less than delta-sigma devices. On the downside, a multiple-chip PGA-SAR converter may exhibit some reliability issues. Battery-powered applications are challenges for both systems: Delta-sigma devices require continuous clocks, and PGA-SAR units may have components lacking shutdown pins.

Summarizing the last four articles from this series—"Which system is best for handheld meters, data loggers, automotive systems, and monitoring systems: a PGA-SAR ADC or a delta-sigma ADC?"—I can only say that the delta-sigma ADC has arrived. It is a viable alternative to the traditional SAR-ADC system. EDN

REFERENCES

1 Baker, Bonnie, "System or technology dictates ADC choice," *EDN*, March 18, 2010, pg 20, http://bit.ly/90m15j.

2 Baker, Bonnie, "Comparing SAR and delta-sigma ADCs' throughput times," *EDN*, April 22, 2010, pg 18, http://bit.ly/92UN07.

3 Baker, Bonnie, "The best solution brings accuracy," *EDN*, May 27 2010, pg 18, http://bit.ly/cJlj51.

4 Baker, Bonnie, "Third round: Look at repeatability," *EDN*, June 24, 2010, pg 20, http://bit.ly/dAuHwB.

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BRIAN DIPERT • SENIOR TECHNICAL EDITOR

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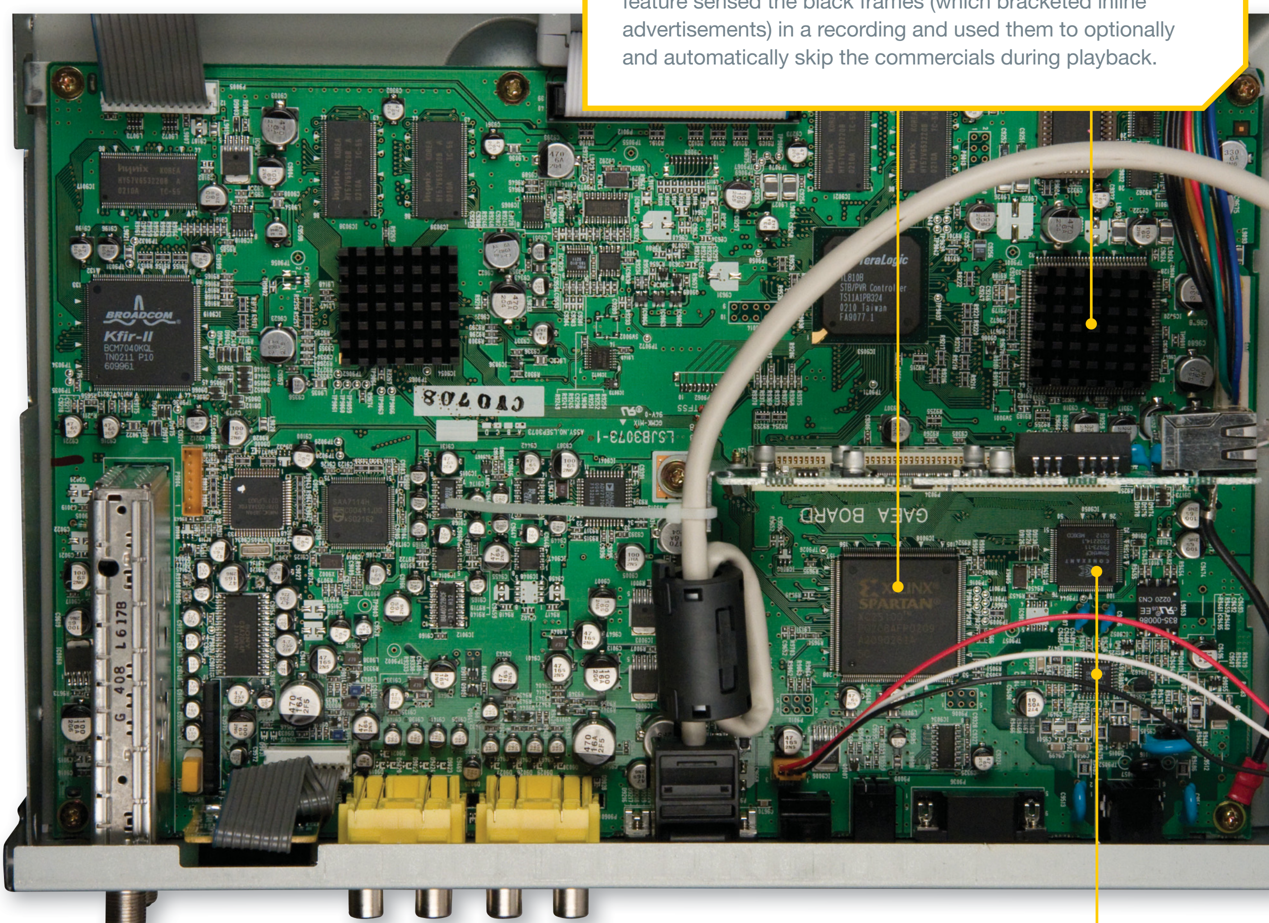
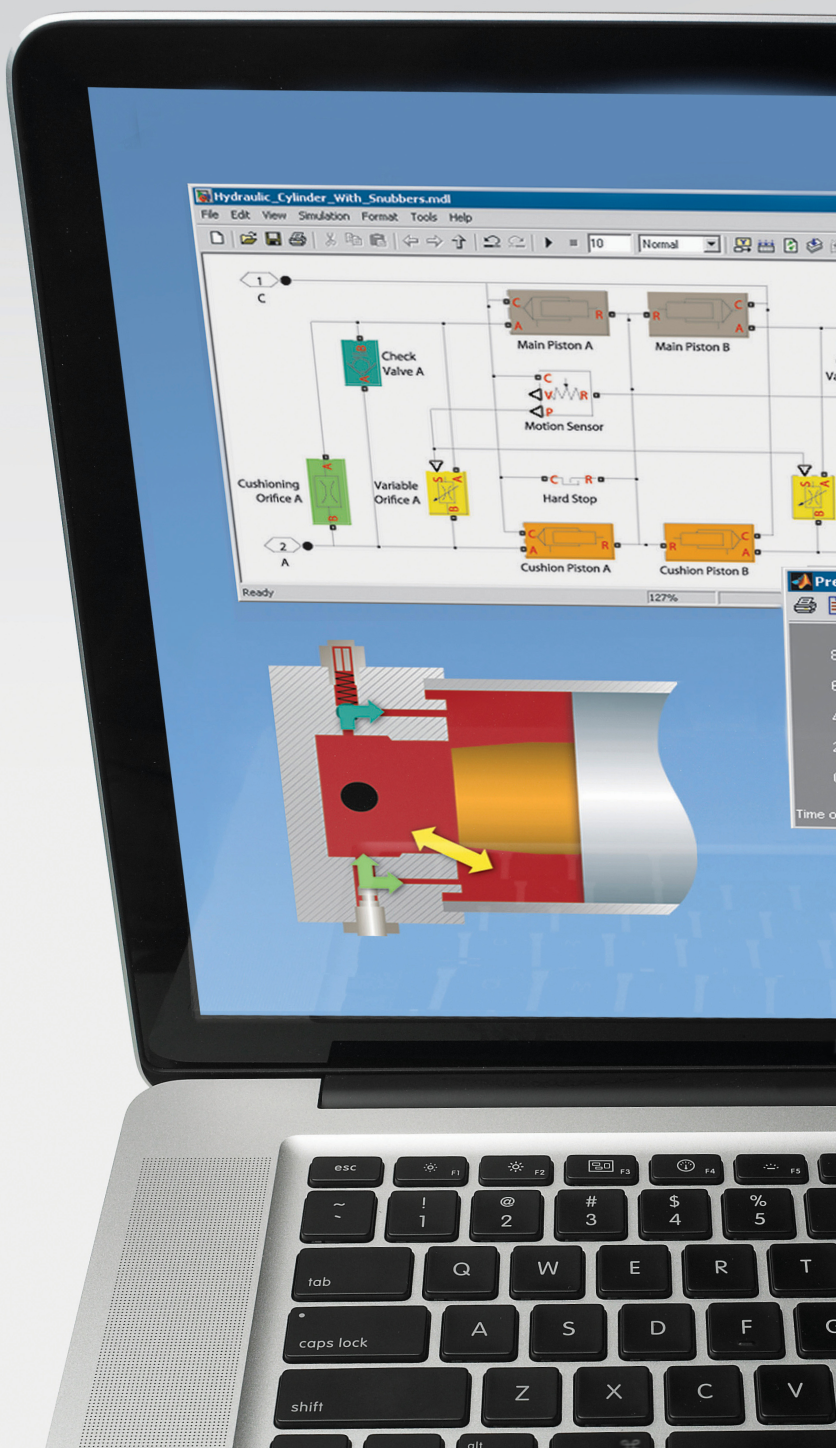
ReplayTV: too gutsy?

Do you need a tangible example of the power of Moore's Law-fueled semiconductor-single-chip integration? Try removing the top from a decade-old piece of consumer-electronics gear. This particular Prying Eyes patient is ReplayTV's 4x00-series PVR (personal video recorder), a groundbreaking device of the time that was eventually retired by legal decree.

The processing heart of RTV4x00-series PVRs, a 250-MHz, MIPS-based, 32-bit PMC-Sierra CPU, ran the Wind River Systems VxWorks operating system and was hardware-paired with a Xilinx XC2S100E FPGA. According to a lawsuit that numerous TV networks filed in late 2001, the processor-plus-software implementation attacked the "fundamental economic underpinnings of free television and basic nonbroadcast services." The networks protested that a "commercial-advance" feature sensed the black frames (which bracketed inline advertisements) in a recording and used them to optionally and automatically skip the commercials during playback.



This unit is the RTV4508, which contains an 80-Gbyte, 5400-rpm PATA (parallel advanced-technology-attachment)/100 3.5-in., dual-platter hard-disk drive. The RTV4508 is nearly identical to its RTV4080 predecessor, except for the addition of analog POTS (plain-old-telephone-system) dial-up capabilities, which ReplayTV implemented with Conexant's CX20463 modem and CX20437 voice-codec ICs, to supplement the Ethernet port because residential LANs were then rare. Also, with the RTV4500 series, Sonicblue, competing with TiVo, lowered the base price to improve the units' retail attractiveness. However, the company then required that consumers pay a $250 "lifetime-activation fee," which effectively made the units just as expensive as their RTV4000-series precursors. An optional per-month subscription plan was also available.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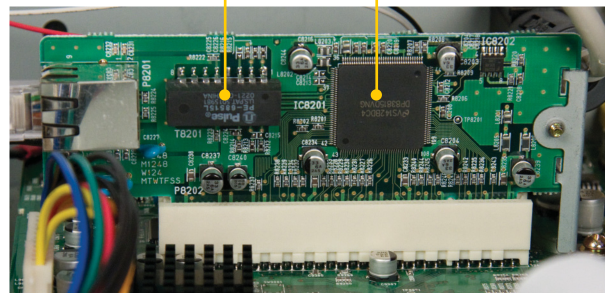
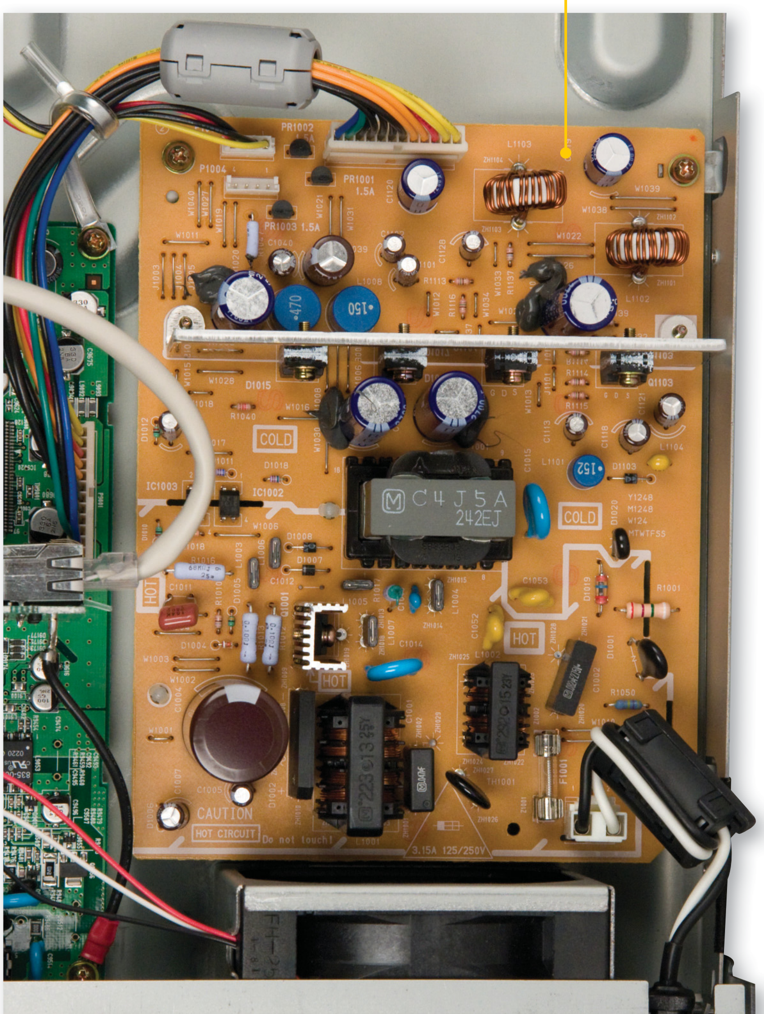
File Edit View Simulation Format Tools Help
Check Valve A
Main Piston A
Main Piston B
Motion Sensor
Cushioning Orifice A
Variable Orifice A
Hard Stop
Cushion Piston A
Cushion Piston B
Ready
127%

The RTV4508 combines National Semiconductor's DP83815 10/100-Mbps Ethernet MAC (media-access controller) and a Pulse Engineering PE-68515L transformer on a PCI (Peripheral Component Interconnect) add-in card. Ethernet connectivity prompted one of the key RTV4x00-series advancements that fueled the ire of the entertainment industry. The advancement was a "send-show" feature that allowed users to stream lossless digital copies of broadcasts to a similar ReplayTV unit within the same local network and to transfer shows to a similar ReplayTV unit on the local network, across the Internet, or to a PC (http://en.wikipedia.org/wiki/ReplayTV). The broadband connection also allowed users to download program guides from ReplayTV's servers.

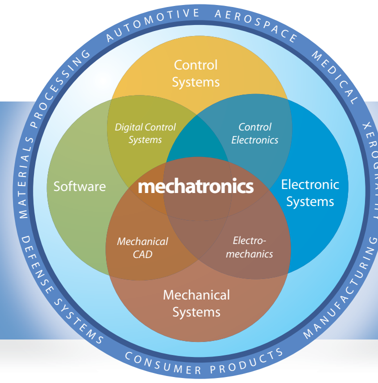


Speaking of integration trends, check out the substantial (5×7.25-in.) size of the power-supply PCB (printed-circuit board) in this roughly 10-year-old design!



The RTV4x00 series recorded one channel's worth of incoming analog video, either from an NTSC (National Television System Committee) tuner or from composite or S-video inputs, to the hard drive in MPEG-2 video and MP2 audio formats. ReplayTV's devices supported both time-shifted- and "live"-playback modes common to the PVR genre, thereby explaining the TeraLogic (later Oak Technology, then Zoran) TL850 digital-TV decoder and TL810 multitransport demultiplexer with HDD controller in the design, along with the Broadcom BCM7040 digital A/V encoder and multiplexer. Other relevant ICs include Analog Devices' ADV7170 video encoder, Burr-Brown's (now Texas Instruments') PCM1725 two-channel audio D/A and PCM1801 A/D converters, NEC's uPD78F0034 microcontroller, Philips Semiconductors' (now NXP Semiconductors') SAA7114 video decoder, Rohm's BU4052BCF analog audio multiplexer/demultiplexer, and Sony Semiconductors' CXA2064 audio decoder and multiplexer. Nowadays, most if not all of these disparate features are found integrated within a single semiconductor slab of silicon.

Semiconductor memories in the ReplayTV include a Fujitsu (later Spansion) 29F040C 4-Mbit NOR flash memory (mated to the TeraLogic TL810), three Hynix HY57V653220 64-Mbit SDRAMs (one each for the Broadcom and two TeraLogic chips), and a Fairchild NM93C46LMB 1-kbit serial EEPROM (on the PCI networking add-in card).



System-motion fundamentals

Tossing stuff into the air helps us understand moments of inertia and principal axes, which are essential for design.

Take any book and wrap a few rubber bands around it. Toss the book in the air three times, each time giving it a pure rotation, as best you can, about one of the three axes perpendicular to its sides. What do you observe? This simple experiment demonstrates fundamentals essential to the design of rotating machines, space satellites, and much more.

The motion of any system depends on the forces acting on it and its constitution—that is, the manner in which its mass is distributed, usually in response to strength, weight, space, and stiffness requirements. To predict dynamic behavior, all you need to know are the mass; the location of the mass center; and six quantities, the inertia scalars.

The concept of mass center is well-known, and you use its location to determine the translational motion of a body. Inertia scalars are not well-understood, however. At any point in a body, you can determine six independent quantities: the three mass moments of inertia and the three products of inertia. Together, the inertia scalars quantify how mass is distributed with respect to three mutually perpendicular axes fixed in the body at that point. The mass moments of inertia quantify the resistance of the body to angular acceleration about each axis; the products of inertia quantify the symmetry of the mass distribution with respect to each plane. The axes are always arranged in an orientation such that the products of inertia are all zero.

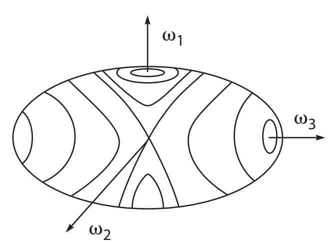


Figure 1 The lines are the intersections for a fixed value of T and various values of H, where $I_1>I_2>I_3$.

Returning to your tossed book, the only force acting on the book is gravity, and that force goes through the mass center. The book, then, is moment-free, spinning freely in space. Neglect any translation of the book and consider just its rotation. Because the book is moment-free, the magnitude of its angular momentum vector, H, must be constant (conserved), and, because you are neglecting translation, its rotational kinetic energy, T, must be constant (conserved). Plotting the constancy of T and H using the absolute angular velocities ω_1, ω_2, and ω_3 as ordinates gives two ellipsoids.

The only allowable spinning states are at the intersections of these two ellipsoids. The lines in **Figure 1** are the intersections for a fixed value of T and various values of H, where $I_1>I_2>I_3$. The three intersections are circles at the greatest and least axes and a saddle at the intermediate axis, indicating that rotation about the axes with the greatest and least moments of inertia is stable to small oscillations, and rotation with respect to the intermediate axis is unstable to small oscillations. This situation is just what you observed in the book experiment.

Another way to arrive at the same conclusion is by considering Euler's equations for this situation, in which the 1, 2, and 3 axes are body-fixed principal axes through the mass center. If the body is given a constant spin rate, Ω, exactly about any one if its principal axes, it will continue to spin about that axis. But what happens if an angular velocity, ω_p, perturbs that motion? Let's assume $\omega_1=\Omega+\omega_p$. Analysis of Euler's equations with linearization shows the resulting equation. If the coefficient of ω_2 is negative, the solution for ω_2 grows with time. This scenario happens if the 2 axis is the intermediate principal axis.

Let's bring the topic of principal axes to everyday practice. Modern machines have high-speed rotors fastened to shafts (**Figure 2**, which is available in the online version of this article at www.edn.com/100729mech). If the principal axis of the mounted object—in this case, a homogeneous solid disk—does not coincide with the axis of the shaft, making the system dynamically balanced, as the angle ω=0 indicates, then dynamic bearing reactions result that could lead to premature bearing failure.

Understanding fundamentals and the ability to apply them to engineering applications are the hallmarks of a complete engineer. **EDN**

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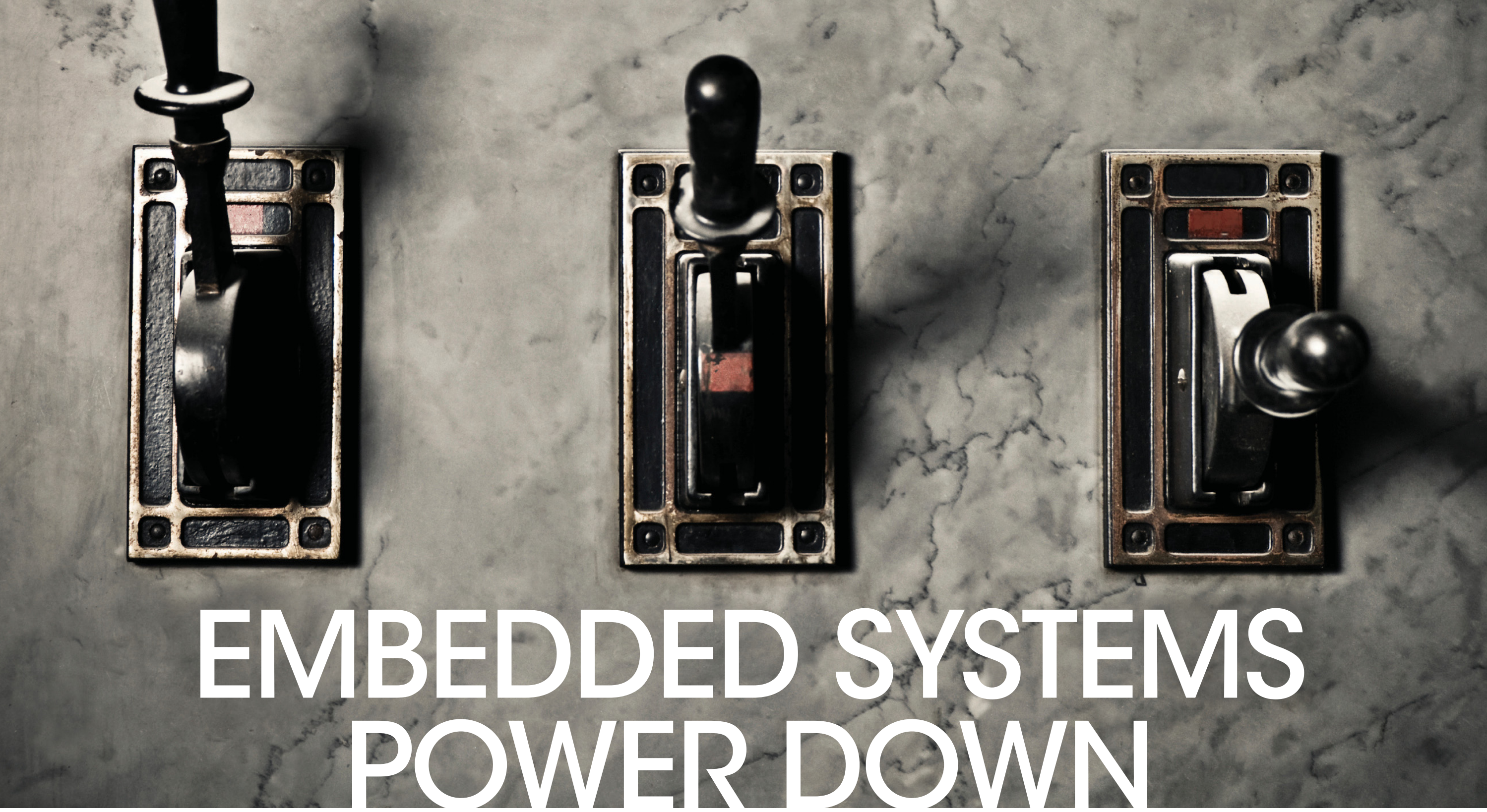

EMBEDDED SYSTEMS POWER DOWN

LOW-POWER SENSORS, MICROCONTROLLERS, AND COMMUNICATIONS CIRCUITS COMBINE TO ACQUIRE, PROCESS, AND TRANSMIT DATA IN APPLICATIONS RANGING FROM ENVIRONMENTAL MONITORING TO HEALTH CARE.

BY RICK NELSON • EDITOR-IN-CHIEF

Applications ranging from health care to environmental, structural, and spectrum monitoring are driving the need for low-power sensors that will permeate our world, delivering data that enhances our quality of life. Reporting on ubiquitous sensors in May, Technical Editor Margery Conner estimated that manufacturers will develop and deploy 1000 sensors per person over the next 10 years, amounting to more than 1 trillion sensors (**Reference 1**).

Those sensors in turn will produce a lot of data for processing. Perhaps that processing will take place in remote server farms, but it's a good bet that at least some processing will occur within embedded microcontrollers near the sensors themselves. The resulting data then will need transmitting—often over a wireless link. The entire operation—sensing, processing, and communications of the results—must take place with extremely low power consumption, affording low heat dissipation and long battery life or, perhaps, elimination of the battery through energy-harvesting techniques (see **sidebar** "Algorithm measures battery's state of charge"). Design-automation tools will be necessary to help bring sensor-based products to market in a cost-effective and timely manner. Since Conner's May 27 cover story, participants at two events have addressed these issues. The IMEC Technology Forum took place in June in Eindhoven, the Netherlands, and Leuven, Belgium; the DAC (Design Automation Conference), took place during the same month in Anaheim, CA.

A SUSTAINABLE WORLD

Speaking at the IMEC Technology Forum, IMEC's president and chief executive officer, Luc Van den hove, painted a picture of a world that will look significantly different in 2025. Innovations will span high and low tech, he suggested, with radiant tiles dimming automatically to control electric costs, with rooftop grass providing cooling and turning greenhouse gases into oxygen. Not surprisingly, IMEC is focusing on the high-tech solutions. "Working toward a sustainable world is one of the most important issues our society is facing," Van den hove said, explaining that energy use has increased 35% over 10 years. "We have to adapt our lifestyle to use less energy," he said, adding that the smart grid will be a crucial technology in that effort. IMEC will contribute to smart-grid and other green-energy implementations with, for example, its research into gallium-nitride power devices and materials for super capacitors, batteries, photovoltaics, and fuel cells.

IMEC is placing much effort into health care. Emerging technologies will enable pregnant women to receive weekly checkups at home, and smart labeling will enable them to choose the right foods. Researchers at the Holst Centre, a research affiliate of IMEC,

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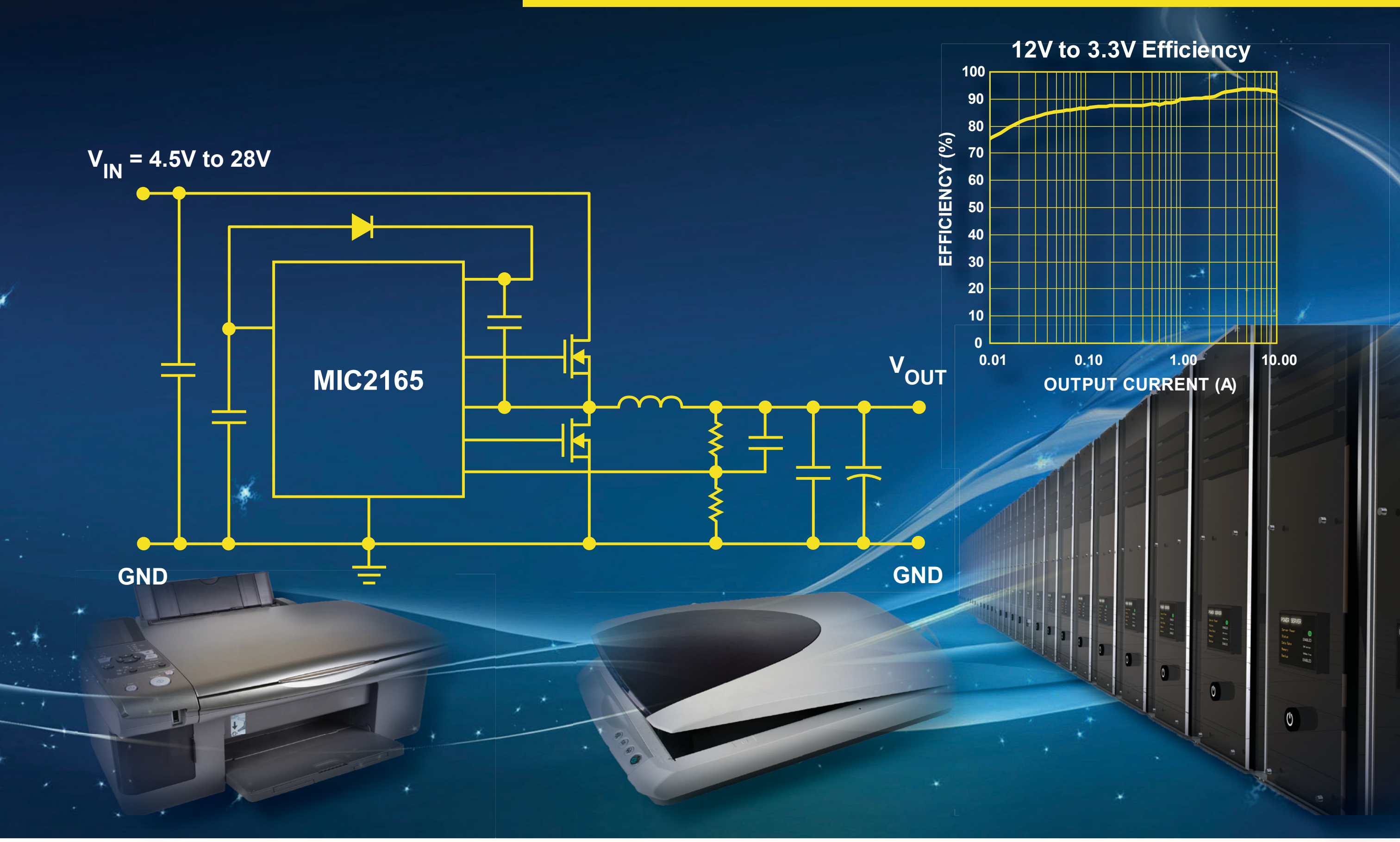

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apply technology to meet societal challenges and needs. They elaborated on relevant health-care efforts and the sensor technologies they are pursuing that will help bring Van den hove's vision to reality (**Reference 2**).

Jo De Boeck, senior vice president of smart systems and energy technology at IMEC and a director at the Holst Centre, provided an overview of the organization's efforts to reduce energy consumption and promote electronic-health initiatives. The technologies under development include innovative sensors and actuators, ultra-low-power DSPs, low-power analog circuitry, ultra-low-power wireless technology, and micropower-generation technologies.

HEALTH-CARE OPPORTUNITIES

Health care offers particular opportunities as aging and chronically ill people worldwide tax health-care efforts. Worldwide, 1 billion people are overweight, 1 billion people are 60 years of age or older, and 1 billion people are chronically ill. The Holst Centre's Human++ initiative provides at-risk populations with preventive, predictive, personalized, and participatory health-care technology. The ultimate goal is a closed-loop system involving symptoms, testing and monitoring, diagnosis, and treatment. In support of the effort, the Holst Centre is developing ultra-low-power technology that eliminates or reduces the need for battery replacement, as well as unobtrusive sensors and other devices that are implantable or comfortable, wearable, and stretchable. The Centre is working on sensors that can analyze sweat, breath, saliva, and a patient's environment.

Julien Penders, program manager for body-area networks in the Human++ program, provided some examples of the Centre's efforts by describing IMEC's ECG (electrocardiogram) necklace. The wearable device provides continual monitoring for a week and offers a body-area-networking interface to an Android phone, making data available over the Internet; the device can send warning e-mails or text messages. One application for ECG monitoring is epileptic-seizure detection, said Penders, adding that 50 million people worldwide suffer from the condition, which costs $15.5 billion in direct and indirect costs each year in the United States alone. IMEC's low-power ECG system includes an algorithm that recognizes heart-rate patterns associated with seizures and notifies health-care providers.

AT A GLANCE

- Emerging low-power technologies will serve health-care applications, enabling devices such as e-noses.
- Low-power processing will be important for energy-efficient sensor deployment.
- Off-the-shelf components provide for efficient design but may offer less-than-optimal power savings.
- Standards to capture power intentions will help designers deal with an always-connected mobile world.
- Cognitive radios are key to energy savings and capacity improvements.

Other efforts center on arousal and stress monitoring, based on sensor technology that monitors the autonomic nervous system. Studies have monitored the psychological state of day traders, who may be on the verge of making irrational deals, and chess players. Relevant multimodal sensing technology in such applications monitors such factors as skin conductance and ECG, with work under way on adding EEG (electroencephalogram) and the sensing of chemicals such as cortisol, a biomarker for stress.

BODY-AREA NETWORKING

To be effective in wearable and implantable applications, sensors and the associated interfacing technology must be low-power, said Bert Gyselinckx, general manager for the Holst Centre/IMEC and program director for Human++. To that end, the Holst Centre has developed a body-area-networking toolbox employing nanowires, nanoparticles, clamped beams, capacitive and oscillator readouts, processing, energy harvesters, and wireless transceivers. A power-estimation tool describes the power performance of combinations of such tools. A radio can account for about half of the power such a system uses, so IMEC and the Holst Centre have been focusing on wireless technology with the goal of outperforming standard wireless technologies such as Zigbee and Bluetooth with respect to power consumption. Gyselinckx described an IMEC-developed event-driven radio that operates on less than 0.1 mW and a 2.4-GHz body-area-network transceiver that offers data rates of 64 to 1024 kbps. It employs OOK (on/off-keying) signaling and a superregenerative-receiver ar-

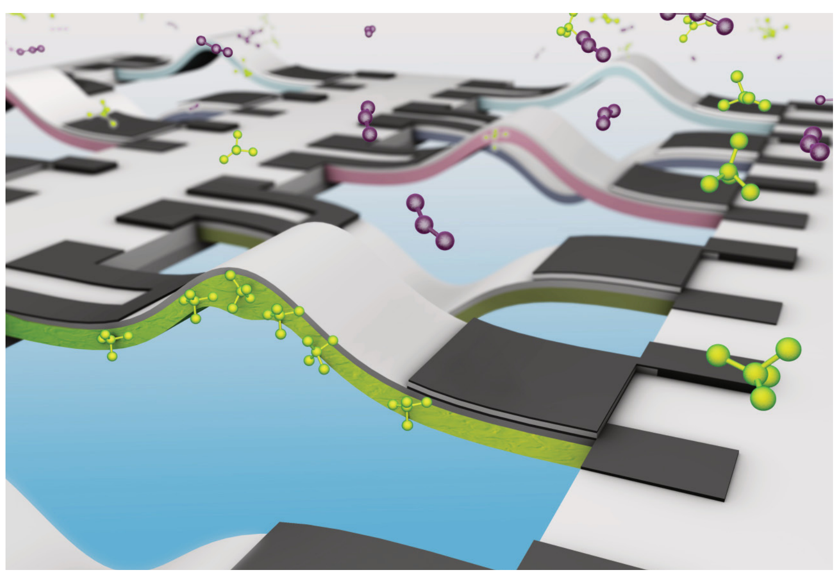


Figure 1 In this MEMS-based electronic nose, a MEMS bridge acquires extra mass in the presence of volatile chemical vapors, changing its piezoelectric characteristics. Arrays of such MEMS bridges can resolve and identify multiple chemical contaminants in an environment and help warn allergy or asthma sufferers to avoid potentially harmful environments.

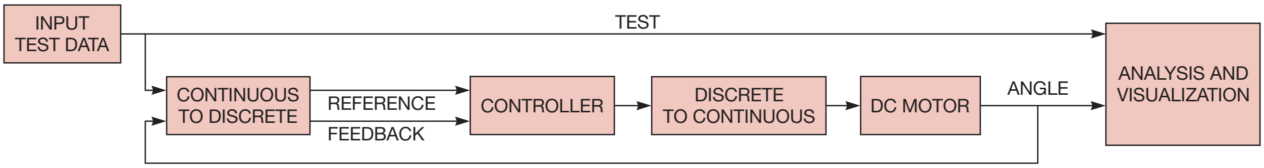


Figure 2 Standard microcontrollers and software tools can speed your time to market for systems such as this motor controller, employing a TI Piccolo processor. Tools from The MathWorks support algorithm and model-based design, simulation, code deployment, and processor-in-the-loop testing.

chitecture. It draws 1 mW as a receiver, 2.5 mW as a transmitter at 0 dBm, and only 0.9 mW transmitting at −10 dBm. Its range is 3 to 5m.

Another health initiative centered on an electronic nose. Mercedes Crego-Calama, principal researcher at Holst Centre/IMEC and program director for Human++, described a MEMS (microelectromechanical-system)-based e-nose in which a MEMS bridge acquires extra mass in the presence of volatile chemical vapors, changing its piezoelectric characteristics (**Reference 3** and **Figure 1**). Arrays of such MEMS bridges can resolve and identify multiple chemical contaminants in an environment and help warn allergy or asthma suffers to avoid potentially harmful environments. The MEMS-bridge architecture operates at lower powers than do alternative cantilever-based approaches.

Crego-Calama also described a low-cost manufacturing approach, in which ink-jet-printing technology can deposit on the MEMS structures the polymers sensitive to chemical vapors. The e-nose can monitor air quality; identify pathogens; monitor food ripeness or spoilage; monitor physiological conditions from breath analysis, for example; and detect biological or chemical weapons.

PROCESSING THE RESULTS

Whatever types of sensors you are deploying, you'll need to process the results—for data logging, to generate alarm signals, or perhaps to remind patients to take their medicine. The approach that can most quickly get you to market is to employ off-the-shelf low-power microcontrollers, such as the Texas Instruments TMS320C2000 Piccolo real-time-control microcontrollers. Such an approach also helps you take advantage of off-the-shelf software tools that can help you develop your algorithms and port them to the target controller.

To support such an approach, The MathWorks and Texas Instruments have announced that they will continue to collaborate to support customers who are designing cost-sensitive, energy-efficient applications. As part of an initiative the companies announced in June, engineers using TI's TMS320C2000 Piccolo real-time-control microcontrollers can adopt model-based-design techniques to support the full product-development chain—from algorithm development to production code generation (**Reference 4** and **Figure 2**). Adding support for the low-cost, high-performance Piccolo family, The MathWorks' target-support package offers rapid turnkey implementation, early verification, and faster time to market for digital-motor-control, digital-power, lighting, renewable-energy, and other applications requiring real-time control.

Previewing the announcement at DAC, Ken Karnofsky, senior strategist for signal-processing applications at The MathWorks, said that creating energy-efficient designs is quickly becoming the most important part of embedded development. "Model-based design helps embedded-system developers reach the market faster with innovative products that harness the low-cost, high-performance, and control-oriented peripherals of Piccolo microcontrollers," he explained.

The MathWorks/TI collaboration enables engineers to design and simulate systems, generate code, and verify algorithms running on TI Piccolo processors using The MathWorks' Embedded IDE (integrated-development-environment) Link tool. The MathWorks' code-generation products enable engineers to integrate peripheral devices and real-time operating systems with algorithms they created using Simulink models, Stateflow charts, and embedded Matlab, all without writing low-level drivers and runtime code. The MathWorks' Fixed-Point Advisor tool helps target floating-point implementations to a fixed-point processor. After deploying the resulting executable on a Piccolo microcontroller or another C2000 microcontroller from TI, engineers can perform processor-in-the-loop testing. To speed execution, engineers can replace parts of the standard ANSI C code with processor-optimized functions.

The 32-bit Piccolo family offers a range of performance levels, various flash options, analog integration, and control-oriented-peripheral options to meet the varying demands of cost-sensitive, real-time control applications. Design engineers can now execute their Matlab and Simulink algorithm code across all F2802x/F2803x Piccolo devices for rapid prototyping and production deployment of embedded systems. Model-based design with production-code generation creates a direct connection between the development environment and the implementation platform, helping engineers to identify and fix design problems at the system level and easily generate efficient C2000-specific code.

MICROTASKING=LOW POWER

Off-the-shelf, general-purpose components don't, however, give you optimal power savings, which requires a more customized approach. Speaking at DAC, Muhammad Adeel Pasha, a professor at the University of Rennes and researcher at IRISA (Institut de Recherche en Informatique et Systèmes Aléatoires)/INRIA (Institut National de Recherche en Infomatique et en Automatique), described how he and his colleagues are developing a design flow for the generation of ultra-low-power wireless-sensor network-node architectures employing "microtasking" (**Reference 5**). Microtasks become active on an event-driven basis. Effective implementation of a microtask requires hardware specialization to reduce dynamic power and power gating

to reduce static power. Pasha described a complete design flow for microtask implementation from C down to synthesizable VHDL, adding that initial estimates show power savings of one to two orders of magnitude better than that of microcontroller-based approaches.

Several presentations at DAC in addition to Pasha's focused on low-power techniques. For example, Adam Cabe, a professor at the University of Virginia, described work he and his colleagues have performed to reduce SRAM power consumption in standby mode—a critical issue because SRAM caches can dominate the total area of some chips (**Reference 6**). To minimize the idle currents SRAM banks draw when inactive, the University of Virginia researchers employ an implicit voltage-reduction scheme that requires no on-chip dc/dc converters. The approach essentially stacks inactive SRAM blocks in series in a way that maintains the required data-retention voltage on each SRAM block and reduces leakage power by 93%, according to simulations in 65-nm technology.

In yet another presentation focused on low power, Weixun Wang, a professor at the University of Florida, described how he and a colleague, Prabhat Mishra, implemented an intratask pre-emptive dynamic-voltage-scaling scheme that can cut energy consumption by as much as 24% in contrast to savings through intertask voltage-scaling techniques (**Reference 7**).

Academic initiatives such as those that Pasha, Cabe, and Wang described indicate what is possible, but it takes additional effort to bring products to market. Representatives of several companies commented on the commercial aspects of low-power design in a DAC panel discussion that Rob Aitken, an R&D fellow at ARM, moderated (**Reference 8**).

ALGORITHM MEASURES BATTERY'S STATE OF CHARGE

Batteries remain a key piece of the energy puzzle as products go mobile. Lei He, associate professor in the electrical-engineering department of the University of California—Los Angeles, speaking at the Design Automation Conference in June in Anaheim, CA, cited estimates that 10% of power consumed in the United States in 2015 will come from renewable resources, with the figure rising to 25% by 2025. Batteries represent a key technology for storing renewable energy acquired at peak harvesting time for delivery at times of peak demand.

Whether you're employing batteries to power a mobile consumer device or to smooth out fluctuations in wind- or solar-power-generating systems, you can't count on drastic Moore's Law-like increases in battery capacity. Consequently, the best approach is to implement an effective battery-management scheme, which in turn requires knowledge of the battery's state of charge.

He noted that, with many battery models, estimation error can accumulate, and initial model parameters are sensitive to battery type and can be hard to set. He and his colleagues have proposed a universal state-of-charge algorithm (Reference A) that employs frequency-domain system analysis to extract open-circuit voltage from voltage and current measured at the battery terminals.

The algorithm, He reported, is of low complexity, applies to any battery type, and requires neither offline training nor initial setup. The algorithm can extract state of charge with less than 4% error for multiple battery types operating at varying discharge rates.He and his colleagues are working on an FPGA implementation and are collaborating with a vehicle manufacturer on the technology.

REFERENCE

A Xiao, Bingjun; Yiyu Shi, and Lei He, "A Universal State-of-Charge Algorithm for Batteries," Design Automation Conference Proceedings 2010, http://bit.ly/bZSBbi.

S Balajee, an engineer at Texas Instruments India, described what's necessary as we move to an always-on and always-connected mobile world, including standards to capture power intent; power-profiling tools; design-verification, synthesis, and place-and-route flows that address multiple voltage domains; and sign-off tools for validating power-efficiency intent. Toshiyuki Saito, an engineer at Renesas Electronics Corp, cited the importance of "3S": switching activity, size of a chip, and supply voltage. He noted the effectiveness of DVFS (dynamic voltage and frequency scaling) as a low-power design method in which components outside an SOC (system on chip) usually control frequencies and voltages. Saito also mentioned A-DVFS (adaptive DVFS), in which components within the SOC adaptively control supply voltages, and he called on EDA vendors to take on a key role in supporting efficient design of low-power systems. Venugopal Puvvada of Qualcomm India emphasized that an effective power-management scheme for an IC requires a system-level view with accurate power-simulation capability.

EDA VENDORS WEIGH IN

Panelist Koorosh Nazifi, an engineer at Cadence Design Systems Inc, said that EDA vendors are providing automated advanced low-power-design techniques that were once the domain of sophisticated designers with centralized in-house CAD systems. He conceded that this initiative requires more work, especially with regard to mixed-signal SOCs and system-level architecture exploration.

"Energy consumption is a critical design constraint," said panelist Allan Gibbons, principal engineer at Synopsys. "Dark silicon is a real and present challenge. We must be smarter about how we spend our energy budget, and don't push for gigahertz with no regard for energy." You must minimize energy cost in watts per MIPS (millions of instructions per second) when devices are in active mode and avoid wasting energy when devices are doing no useful work in standby mode. "Power consumption is replacing performance as a key figure of merit at [processes of] 32 nm and below," he added. Achieving an optimal approach for energy effi-

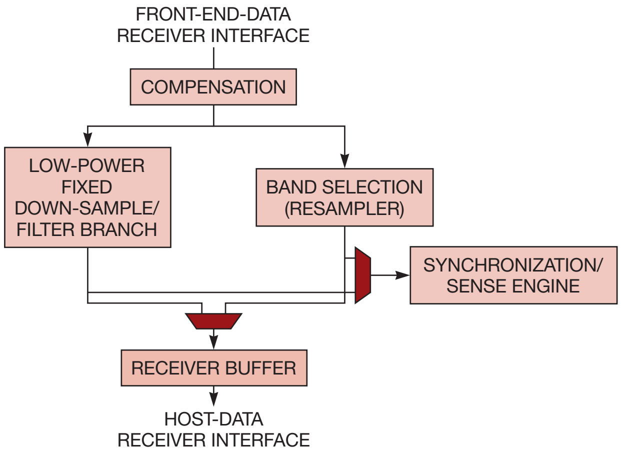


Figure 3 The radio becomes the sensor in pursuit of energy savings and capacity improvements. IMEC's digital front end for sensing investigates the radio-frequency spectrum in which it operates, looking for the most efficient ways to transmit and receive information.

ciency will require power-aware exploration with virtual prototyping, allowing designers to concurrently optimize all components of a design.

THE RADIO IS THE SENSOR

Sensors, processors, and wireless-radio links are all components of a smart sensor; to further pursue improvements in power savings and performance, however, the radio itself must become the sensor (**Figure 3**). Cognitive radios that can respond intelligently to the radio-frequency spectrum in which they are operating will help IMEC reach the goals of its "green-radio" initiative. Speaking at the IMEC Technology Review, Liesbet Van der Perre, director of the IMEC green-radio program, said that the organization is pushing over the next decade for 2000-fold improvements in energy efficiency and a 30-fold improvement in capacity. Reconfigurable radios will be part of the approach to reaching those goals, she said, as will improvements in power-amplifier efficiency, scalable processing and sleep modes, hybrid cell architectures, and router and switch hardware. Also contributing will be advanced antenna-design techniques and MIMO (multiple-input/multiple-output) technology.

Van der Perre questioned how we can keep many-gigabit-per-second communications going. The answer, she said, lies in compact, low-cost, low-power cognitive reconfigurable multimode radios that include spectrum-sensing features to support dynamic use of spectrum. The IMEC approach centers on the Scaldio scalable-radio analog front-end and the COBRA (cognitive-baseband-radio-architecture) digital baseband device (**Reference 9**). The COBRA processor supports 1-Gbps concurrent streams, multithreading with SIMD (single-instruction/multiple-data) capabilities, a FlexFEC (flexible forward-error-correction) processor, and a front end that supports flexible filtering and spectrum sensing. A COBRA template supports fine-tuning to end-user requirements. According to Van der Perre, radio algorithms and architectures are ready to support 4G (fourth-generation) requirements, with sufficient flexibility in resampling and programming filters to meet emerging cognitive-radio, sensing, and multiband-reception requirements.

> Go to www.edn.com/100729df for links to the companies this article mentions.

SYSTEM-LEVEL NEEDS

Universities, companies, and research organizations will continue to pursue low-power sensors, processors, and radios. All could use a boost from EDA vendors. Iqbal Arshad, corporate vice president of innovation products at Motorola Mobile Devices, summed it up during a June 17 DAC keynote address at which he explained how his team developed the Motorola Droid, describing the synthesis of new hardware that tightly couples with new software into a global multiband product. The team did not have all the automated design tools it might have wished for as it pursued its development schedule at breakneck speed, Arshad said, relying instead on reference designs. Building a board is easy, he said, but integrating the entire system was difficult, involving interrelated electrical, mechanical, and other design considerations.

Power-efficient design proved to be particularly challenging. According to Arshad, SOC suppliers tend to think power management ends with their chips, but they are not the key considerations for end users. "There is no tool today to do effective power management for the end product," he said, pointing a clear path to where DAC exhibitors might turn their attentions over the coming year.EDN

REFERENCES

1 Conner, Margery, "Sensors power the 'Internet of Things,'" *EDN*, May 27, 2010, pg 32, http://bit.ly/aWwUJa.

2 Nelson, Rick, "Health care is focus of Holst Centre research efforts," *EDN*, June 8, 2010, http://bit.ly/a6JXL1.

3 Nelson, Rick, "Low-power e-nose checks air quality," *EDN*, July 15, 2010, pg 14, http://bit.ly/aDsARw.

4 Nelson, Rick, "MathWorks adds model-based design for TI's C2000 Piccolo microcontrollers," *EDN*, June 23, 2010, http://bit.ly/cketpK.

5 Pasha, M, et al, "A Complete Design-Flow for the Generation of Ultra Low-Power WSN Node Architectures Based on Micro-Tasking," *DAC Proceedings 2010*, http://bit.ly/bZSBbi.

6 Cabe, A, et al, "Stacking SRAM Banks for Ultra-Low-Power Standby Mode Operation," *DAC Proceedings 2010*, http://bit.ly/bZSBbi.

7 Wang, W, and P Mishra, "PreDVS: Preemptive Dynamic Voltage Scaling for Real-Time Systems Using Approximation Scheme," *DAC Proceedings 2010*, http://bit.ly/bZSBbi.

8 NS, Nagaraj, "What's Cool for the Future of Ultra Low Power Designs?" *DAC Proceedings 2010*, http://bit.ly/bZSBbi.

9 Craninckx, J, and P Wambacq, "Reconfigurable single-chip radios," *EDN*, May 27, 2010, pg 29, http://bit.ly/aySd2P.

BLU-RAY:

DOGGED BY DELAYS, WILL IT STILL HAVE ITS DAY?

BY BRIAN DIPERT • SENIOR TECHNICAL EDITOR

THE SONY-CHAMPIONED BLU-RAY OPTICAL DISC HAS TO DATE SIGNIFICANTLY UNDERSHOT ITS BACKERS' INITIAL FORECASTS. FORMAT WARS AND ECONOMIC RECESSIONS HAVEN'T HELPED MATTERS, BUT IS THERE SUBSTANTIAL MARKET PULL FOR SUCH SUBSTANTIAL STORAGE?

Kazuo Hirai, then president and chief executive officer of Sony Computer Entertainment America, and Ken Kutaragi, at the time the president of Sony Computer Entertainment, likely felt on top of the world when the two corporate executives took to the stage at mid-May 2005's E3 (Electronic Entertainment Expo) in Los Angeles to unveil the PS (PlayStation) 3 game console (**Figure 1**). After all, the PlayStation 2, for which both men held prominent and visible project roles, had handily won that console-generation war, beating back both historical competitor Nintendo's Gamecube and upstart Microsoft's first-generation Xbox (**Reference 1**). In the process, the PS2 had become a key factor in the success of optical-DVD (digital-video-disc) media, by virtue of its DVD-playback capabilities and content-subsidized price tag. Sony hoped that the PS3 would play the same role for next-generation Blu-ray media, not only generating profitable revenue for the Sony Studios movie subsidiary but also regaining the lucrative patent-royalty crown that it and partner Philips had held with the optical CD and subsequently lost to fellow competitor Toshiba in the DVD era (**Figure 2**).

Fast-forward five years, and you'll find that those rosy predictions haven't come to fruition (**references 2** through **4**). DVD-content rentals and sales still eclipse by a substantial margin their Blu-ray counterparts, even though Blu-ray movies and stand-alone players first became available four years ago. "If you get a number of titles hitting 30% of sales in Blu-ray, then that is successful," says Craig Kornblau, president of Universal Studio's home-entertainment sector. When he made that statement last December, the Blu-ray format had garnered only about 14% of the revenue of DVDs, despite having substantially higher per-disc manufacturing and distribution costs (**Reference 5**).

This failure comes despite the fact that several movie studios have offered inexpensive DVD-to-Blu-ray trade-in programs that strive to encourage the format migration of both SD (standard-definition) and HD (high-definition) DVDs to Blu-ray, along with dual-format DVD-plus-Blu-ray "flipper" discs. It comes despite hardware suppliers', content providers', and retail partners' heavy Blu-ray-format promotion and despite the fact that, thanks to cable, IPTV (Internet Protocol television), and satellite-subscription providers' service upgrades, consumers can now discern the improvements of HD images over their SD predecessors. Last summer's transition in the United States from NTSC (National Television System Committee) to ATSC (Advanced Television Systems Committee) over-the-air broadcasts also provided encouragement for consumers' broader migration to HD material versus the SD predecessor (see **sidebar** "A fuzzy future"). And it comes despite faster-than-anticipated content and hardware price decreases, which have led to dubious profitability for vendors

in the supply chain, including building-block-semiconductor companies.

How has the Blu-ray industry arrived at this messy point, and what path—if any—exists for it to achieve eventual success, both fiscally and in other ways? Given this situation, should you consider adding Blu-ray support to your future designs and, if so, when? Both the underlying reasons for and the fading potential exits from this debacle are complex. The Blu-ray quagmire provides a compelling case study of the pitfalls of a short and narrow vision that adapts to neither history's lessons nor today's deviations. This flawed vision assumes that suppliers' push will still ultimately triumph even without a substantial amount of customers' pull.

CONSOLE CONTROVERSY

The Sony PS3 remains an ideal hardware platform for Blu-ray playback, thanks to its substantial processing muscle for both current needs and future feature updates; HDMI (high-definition-multimedia-interface) output; hard-disk-drive-based upgradability; and upgrade-friendly, built-in, wired- and wireless-Internet connectivity. The reasons for its less-than-stellar market performance to date, however, begin with its late-2006 introduction date. Microsoft and Nintendo had launched their Xbox 360 and Wii, respectively, a year earlier, and both their initial consoles and subsequent accessories and content proved tempting to shoppers (**Reference 6**).

Even this setback, under ordinary circumstances, might not have been a deal breaker. Despite its traditional razors-and-blades-subsidized sales mode, however, the entry-level PS3 sold for \$100 more than the premium Xbox 360 variant, \$200 more than the entry-level Xbox 360, and \$250 more than the Nintendo Wii (**Reference 7**). The entry-level PS3 also eliminated key features as a cost-reduction move. For example, it offered neither an HDMI output nor embedded Wi-Fi, had no distinctive cosmetics, and lacked an integrated memory-card adapter. To obtain these capabilities, along with a 20- to 60-Gbyte hard-disk upgrade, would cost \$100 more, pushing the price to more than the all-important \$500 threshold.

Sony has slowly but demonstrably addressed the PS3 pricing problem, along with slimming the console and reducing its ambient noise, albeit with requisite feature retractions. The company first restricted and then eliminated game-content compatibility with the PS2 and, more recently, dispensed with the ability to run other operating systems, such as Linux, on the hardware. It could do little, however, beyond the control over its own game studio's offerings regarding the comparative lack of compelling content—especially, exclusive titles—for the PS3. This dearth was due in large part to the difficult-to-program distributed-processing model employing the unproven Cell CPU architecture, along with third-party developers' skepticism that their development investments would incur an adequate fiscal return.

Sony also had no control over the still-lingering economic crisis that in 2008 gripped the United States—a big problem for a foreign company such as Sony due to currency exchange-rate factors—and rapidly expanded from there to blanket the global economy. Unemployment for many, uncertain futures for those remaining employed, and a credit crunch for everyone prompted many whose PS3 downward-pricing moves might normally tempt to instead keep their wallets in their pockets. Ironically, it conversely was at least a moderate win for Microsoft and Nintendo because their customers had already made the pricey initial hardware investments. These consumers weren't traveling and otherwise going out for entertainment; they instead stayed home with Microsoft's and Nintendo's comparatively inexpensive new games and accessories.

Figure 1 Sony originally envisioned its PlayStation 3 as a Trojan Horse that would bring Blu-ray capabilities to living rooms, but it has yet to fulfill those expectations. The PS3 Slim redesign strove to address the price problem, but is it too little, too late?

AT A GLANCE

- Blu-ray, which has been under development for almost a decade, has yet to hit its full stride.
- Whereas the Sony PlayStation 2's capabilities advanced DVD (digital-video-disc) technology, successor Playstation 3's hiccups have hindered Blu-ray.
- Upscaling DVD players created a pseudo-high-definition presentation that, to many consumers, was good enough and was cost-effective.
- Incomplete standardization of the first-generation product convinced many potential Blu-ray customers to stay on the sidelines until both the format and the gear supporting it matured.
- "Cloud" storage, speedy broadband pipes, and bit-thrifty advanced multimedia codecs threaten to make optical discs irrelevant in the emerging era of Internet-streamed and -downloaded content.

THE ENTRY-LEVEL PS3 ELIMINATED KEY FEATURES. ADDING THEM WOULD PUSH THE PRICE PAST THE \$500 THRESHOLD.

OPTICAL COMPETITION

Whereas Sony had burdened every PS3 with an expensive Blu-ray drive, Microsoft instead sold its now-discontinued HD-DVD player, which partner and key HD-DVD promoter Toshiba supplied, as an optional USB (Univer-

sal Serial Bus) 2-tethered add-on. Besides reducing the base console's cost and consequent price, this accessory move gave customers something else to purchase for a subsequent birthday or holiday, and it created the as-yet-unrealized perception that, if HD DVD lost the format war, Microsoft could switch gears and instead support Blu-ray with a different external drive and associated software. In other words, Microsoft's omission of an integrated HD optical drive preserved consumers' investments in their base consoles, regardless of the outcome of the format war. Sony's integrated drive, on the other hand, would effectively obsolete a notable portion of the PS3's appeal should Blu-ray end up the loser. Given this discrepancy in consumer perception, it's easy to see how the battle, which largely ended in early 2008, almost a year and a half after the PS3's release, further dimmed consumers' enthusiasm for the PS3. HD DVD's foundation technology lives on in the form of the CBHD (China Blue High-Definition Disc), which to date shows strong indication of usurping Blu-ray in that all-important market.

Sony had followed a similar integration strategy with the DVD-inclusive PS2 and for even fewer obvious reasons: Sony Studios would benefit from DVD sales, but Sony's patent presence in DVD was more limited than its presence in Blu-ray. Nevertheless, the DVD-on-PS2 outcome had turned out more positively for the company. The difference this time was that DVD had received a far more unified industry embrace. The format war was less intense and relatively quickly over with DVD.

Another critical factor was that consumers correctly perceived DVD as a greater advancement over the VHS (video-home-system) predecessor than Blu-ray was an advancement over DVD. When DVD emerged, consumers were comfortable with the optical-disc format from years' worth of audio-CD experience. They were also familiar with the audio CD's advantages over cassette tapes: short- and long-term sonic quality, media durability, and fast random access to any segment of the stored content. As a result, they quickly embraced the DVD format.

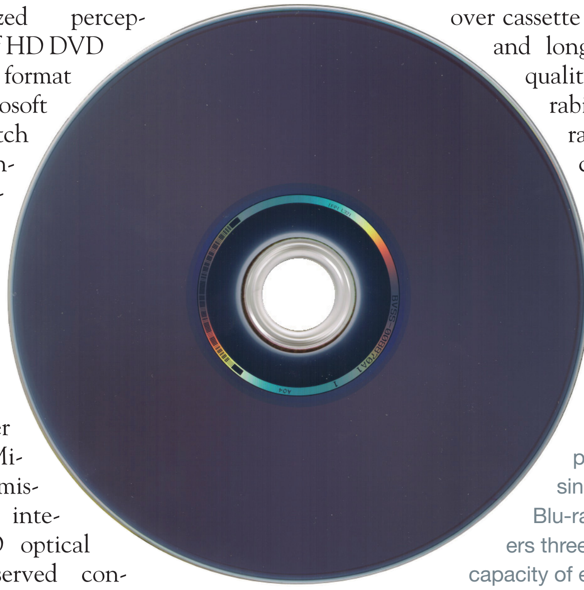
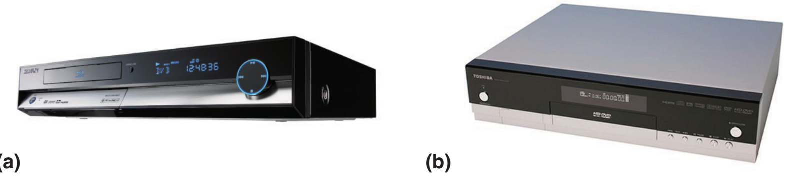


Figure 2 At 25 Gbytes per layer, a single-layer Blu-ray disc delivers three times the capacity of even a dual-layer DVD, yet applications that demand this much storage are slow to emerge.

Blu-ray's primary sales pitch—high-resolution images—was of significance only to consumers whose displays and viewing setups enabled them to discern the quality improvement. Initial Blu-ray offerings, such as the low-quality first-generation *The First Element*, employed the archaic MPEG (Motion Pictures Experts Group)-2 video codec instead of the more modern H.264, also known as MPEG-4 AVC (advanced video coding), MPEG-4 JVT (joint video team), or MPEG-4 Part 10, or VC (video coding)-1, also known as Windows Media Video 9 Advanced. That choice didn't much help matters for Blu-ray's fortunes. And inexpensive DVD players, which used sophisticated upscaling techniques to fill in the pixels absent from the standard-definition 4-by-3 or wide-screen image source, further muddied the high-definition picture.

Analogies to DVD-Audio and SACD (super audio compact disc) versus the CD predecessor are apt (**Reference 8**). In this case, a format war also existed, and the industry was attempt-



(a) (b)

Figure 3 Samsung's $999 BD-P1000 (a) kicked off Blu-ray's attempted conquest of the United States and, in clashing with $799 Toshiba's HD-A1 HD DVD player (b), also broadened the format war beyond a war of words.

ing to move consumers from a conventional to a supposedly higher bit- and sampling-rate presentation. The dueling sound formats even offered native surround-sound enhancements versus their two-channel red-laser audio-CD predecessor. Customers ultimately gave both formats a lukewarm embrace, however, perceiving their predecessor as good enough. The video industry didn't learn from its audio counterpart's problems but instead followed a similar technology-treadmill strategy in the absence of strong customer demand and, thus far, with a largely similar outcome.

STANDARDS IN FLUX

Look beyond prerecorded movies to consumer-generated content, and you'll encounter yet another format fracas. In the post-DV (digital-video) SD era, high-resolution consumer camcorders subdivided into three camps: tape-based HDV (high-definition video) employing high-definition MPEG-2, solid-state-storage-based AVCHD (advanced video codec high definition) leveraging H.264, and largely proprietary hard-disk-drive-based approaches. AVCHD has now garnered the lion's share of the business, partially thanks to flash memory's ruggedness, low power consumption, compactness, and fast-random-access media. Yet it's taken several years for this situation to even begin to sort out. Throughout this time, consumers, content with SD DV cameras and DVD optical-archive and playback media, have delayed upgrading their HD equipment.

Ironically, market-analysis reports consistently conclude that most camcorder owners do no video editing whatsoever, much less burn the results to an optical-disc archive. Instead, they often simply toss tapes or memory cards into a desk drawer or shoe box. Alternatively, they use YouTube and related online services as their content repositories, uploading clips directly from their cameras using USB-tethered computers as intermediary transfer devices. The convenience seems to have trumped the disadvantages: lossy compression and low-resolution images. Analogies to the embrace of MP3 audio are apt. This trend explains the booming popularity of Cisco's Flip flash-memory-based camera line and its competitors from Creative Labs, Eastman Kodak, and other companies. It also explains why many camcorder users were oblivious to the blue-laser-optical-disc-format wars.

Speaking of standards, Blu-ray has undergone several significant evolutionary steps through its short life. Consumers' reluctance to purchase hardware that will inevitably become out of date partway through the evolutionary path is therefore understandable. Initial player generations followed the BD (Blu-ray disc)-Video 1.0, the so-called initial standard or grace-period profile. This profile left optional, therefore largely unimplemented, key features, such as local-storage capability, secondary audio and video decoders—enabling picture-in-picture support, for example—and virtual-file-system support. Profile 1.1 players, which currently still constitute most of the equipment on the market, made improvements in each of these areas, requiring, for example, 256 Mbytes of local storage, thereby enabling the Bonus View limited enhanced-feature mode.

However, Profile 1.1 players extended Profile 1.0's stance of not requiring network-access support. In contrast, HD-DVD players include this capability from first-generation hardware. As such, the Blu-ray players couldn't access Internet-housed added features, for example, and end users could not easily update players' firmware to fix incom-

Figure 4 LG's BD390, a well-known example of the modern media streamer, builds on a Blu-ray foundation with support for network-streamed content, much of it standard-definition in resolution.

patibility bugs they discovered with the release of subsequently published titles. Profile 2.0, the so-called final standard, is the latest published Blu-ray specification iteration. It requires built-in network connectivity and boosts local storage to a minimum of 1 Gbyte. As such, the feature suite that Bonus View formerly branded is now BD-Live.

Managed Copy is another as-yet-unrealized Blu-ray feature that was available in HD DVD from its earliest days. When (or perhaps more accurately if) cognizant hardware implements it, it enables consumers to make legal and bit-accurate digital copies of discs they've purchased. The mention of "copies" inevitably leads to the broader topics of digital-rights management and content encryption, which have also undergone development during Blu-ray's lifetime. Initial discs relied solely on the AACS (Advanced Access Content System), an expansion of DVD's CSS (content-scrambling system), which, like its CSS predecessor, hackers quickly cracked. The Blu-ray Association's response, BD+, leveraged a virtual-machine-architecture approach. Hackers have cracked it, as well, as software products such as SlySoft's Any-DVD HD suggest. Offshore manufacturers often develop these products; as such, they are beyond the reach of US copyright-court jurisdiction.

MANAGED COPY ENABLES CONSUMERS TO MAKE LEGAL DIGITAL COPIES OF DISCS THEY'VE PURCHASED.

Hollywood is even concerned with real-time degraded copies that individuals might create through intermediary digital-to-analog and digital-to-analog transformations using a player's component-video outputs. As such, a revision of the Adopter Agreement that the AACS Licensing Authority released last year requires manufacturers to phase out by 2013 all unencrypted—that is, analog—video outputs in players. For the near term, such a move may stimulate Blu-ray-hardware sales to consumers whose displays lack or have too few digital inputs (**Reference 9**). For the long term, however, such potential customers, also including those whose displays support now-obsolete HDMI generations, will be loath to embrace Blu-ray by virtue of the substantial incremental expense they'll need to shoulder in the form of new TVs.

STREAMING SUCCESSOR?

Concerning the price decreases that are occurring more rapidly than manufacturers intended for Blu-ray players and media, consider that the first Blu-ray player in the United States, Samsung's BD-P1000, which the company released in June 2006, initially cost $999 (**Figure 3**). Toshiba's rival HD-A1, which it released roughly two months earlier, originally sold for $799. Last year, during a "Black Friday" promotion, Walmart sold the Magnavox NB500 Blu-ray player for $78, a roughly 13-fold price reduction from that $999 starting point. Nowadays, more than four years after the BD-P1000 first went on sale, Blu-ray players selling for less than $100 are commonplace. Even if you assume that consumer-electronics manufacturers are still clinging to at least a modicum of profitability despite this rapid price decrease, you can imagine the cost pressure that they're passing along to their building-block-IC suppliers.

Ken Lowe, vice president of marketing at Sigma Designs, indicated early this year that, as a result of the cost pressures, the company had withdrawn its interest in entry-level Blu-ray-only designs, preferring instead to focus on more lucrative value-added platforms. He refers to the new generation of set-top-boxes, devices that begin with a Blu-ray base and augment it with network-connection-enabled playback of Internet-based content from sites such as Amazon Videos On Demand, Hulu, Netflix, Pandora, and Yahoo, along with access to LAN NAS (network-attached-storage)-stored audio, video, and still-image material (**Figure 4**).

Ironically, much of this content is SD in native resolution. The local playback device then dynamically upscales it to

match the pixel count of the destination display. Manufacturers are doing whatever it takes to sell gadgets in the near term. The sales of these gadgets, however, are, for the long term, negatively affecting Blu-ray's fundamental sales premise: high-quality "true," high-resolution content. Netflix even last year brought streaming support to the PS3. Netflix streams HD content to consumers if their broadband connections support the necessary bit rates, but such material is high-resolution only in the strictest pixel-count definition of the term. Its aggressive compression renders it generally inferior to 720p and 1080i ATSC broadcasts, for example.

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Reed Hastings, chief executive officer of Netflix, has repeatedly mentioned his company's long-term aspirations to get out of the disc-shipping business and move to a streaming-delivery model. This move would substantially reduce the company's operating costs by eliminating warehousing, processing, shipping, postage, and lost-and-damaged-goods expenses. Netflix's job site recently posted a presentation in which the company forecasts that the disc-by-mail business will peak in 2013, after which content streaming

NETFLIX ASPIRES TO LEAVE THE DISC-SHIPPING BUSINESS AND MOVE TO A STREAMING-DELIVERY MODEL.

A FUZZY FUTURE

Underwhelming performance to forecasted expectations aside, it's clear that Blu-ray has secured sufficient industry support to ensure its longevity for many years to come. If the optical-disc format is optimal for your future designs and if the dual-layer DVD's (digital-video disc's) 8.5 Gbytes of capacity are insufficient for your needs, then you may want to consider implementing Blu-ray support. Conversely, DVD's comparative maturity and broader industry-sourcing ecosystem will likely make it the more economical choice. Can your application tolerate, for example, three dual-layer DVDs' worth of storage instead of one single-layer Blu-ray disc? Other storage options should also be on your evaluation list: small-form-factor hard drives, flash memory in various form factors, and even "cloud" storage, for example.

What factors may eventually enable Blu-ray to achieve its initial goals, displacing DVD as the pre-eminent optical-disc format? It's unclear that console gaming will be Blu-ray's salvation. Although Sony touts the capacity that only Blu-ray supposedly delivers, Microsoft and its partners seem to be managing just fine with DVD on the Xbox 360, and a close inspection of PlayStation 3 titles' disc contents reveals a disproportionate amount of capacity that bit-heavy but low-value video "cut" scenes use.

Figure A Panasonic and other consumer-electronics manufacturers hope that 3-D TV provides a compelling emerging justification for Blu-ray's substantial capacity.

On the other hand, 3-D TV is a more legitimate use of Blu-ray's per-disc storage potential (Figure A and Reference A). An ideally coded presentation stores roughly twice as much per-frame information, including discrete right- and left-eye views, as a conventional 2-D variant. Double the frame rate, and the storage demands can potentially double again. What may be ideal is not always necessary, however. You can squeeze two eyes' worth of data into the storage and transmission capacity of one eye's view, but this approach involves resolution, frame-rate, and other quality trade-offs that the viewer may not perceive.

REFERENCE

A Dipert, Brian, "Coming soon: 3-D TV," *EDN*, April 8, 2010, pg 24, http://bit.ly/dbBAnv.

will drive business growth. The presentation estimates that 100 million households in the United States currently have pay-TV subscriptions and contrasts that figure with Netflix's 14 million subscribers at the end of March, which the company expects to rise to 17 million by year-end.

Apple is another strong advocate of Internet-based content delivery, as its online iTunes store demonstrates. You might expect that a portion of the company's desktop and laptop computers would by now have incorporated built-in Blu-ray burners, given Apple's longstanding embrace of multimedia and the dominance of the Mac in multimedia-content creation. At press time, however, Apple was still relying exclusively on third-party hardware and software partners to bring Blu-ray support to the Mac ecosystem. Blu-ray's capacity isn't even necessary for hard-drive backups; the Mac 10.5 and 10.6 operating systems contain Time Machine, a feature that automatically and periodically mirrors content to a USB- or network-tethered hard drive.

The company's mercurial chief executive officer, Steve Jobs, referred to the Blu-ray situation as a "bag of hurt" during a 2008 press conference. Many in the industry, however, believe that the company's rejection of Blu-ray is a strategic move to accelerate adoption of the presumed online-delivery heir apparent. Microsoft made public its similar aspirations in response to Toshiba's decision to shutter its HD-DVD efforts in February 2008, indicating that it had no intention of offering a Blu-ray accessory for the Xbox 360 but would instead focus its development and promotion efforts on consumer purchases and rentals from its Video Marketplace, now known as the Zune Marketplace. Blu-ray founder Sony has even entered the act, offering rentals and purchases of movies and other video material from an online store accessible through the PS3. EDN

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www.sony.com

Toshiba
www.toshiba.com

Universal Studios
www.universalstudios.com

Walmart
www.walmart.com

Yahoo
www.yahoo.com

REFERENCES

1 Dipert, Brian, "Cutting-edge consoles target the television," *EDN*, Dec 20, 2001, pg 47.

2 Dipert, Brian, "Upward spiral: optical storage," *EDN*, Aug 7, 2003, http://bit.ly/a0AxJX.

3 Dipert, Brian, "Beating the blue-laser blues," *EDN*, Aug 4, 2005, pg 35, http://bit.ly/aaDWs1.

4 Dipert, Brian, "Subpar wars: High-resolution-disc formats fight each other, consumers push back," *EDN*, March 2, 2006, pg 40.

5 McBride, Sarah, "Hollywood Studios Push Blu-ray Sales for Holidays," *The Wall Street Journal*, Dec 14, 2009, http://bit.ly/bdoYw3.

6 Dipert, Brian, "Got game? Living-room consoles grapple for consumers' eyes, wallets," *EDN*, Dec 16, 2005, pg 51.

7 "Freebie marketing," Wikipedia, http://en.wikipedia.org/wiki/Freebie_marketing.

8 Dipert, Brian, "Expanding options bring surround sound to the forefront ... and the back ... and the sides ... and the ceiling ... and the floor ...," *EDN*, Jan 10, 2002, http://bit.ly/cnnuUI.

9 Dipert, Brian, "Connecting systems to displays with DVI, HDMI, DisplayPort: What we got here is failure to communicate," *EDN*, Jan 4, 2007, pg 46, http://bit.ly/c5YtAE.

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BY JONSENSER ZHAO • PULSE

A new calculation for designing multilayer planar spiral inductors

A NEW, SIMPLE, AND ACCURATE EXPRESSION LETS YOU CALCULATE THE COUPLING FACTOR BETWEEN MULTILAYER PCB INDUCTORS.

Planar spiral inductors are less expensive than either chip or coil inductors for PCB (printed-circuit-board)-based designs. Accuracy in designing a spiral inductor is important because it is difficult to modify the inductor once you have built it on the PCB. Some formulas are available for calculating the spiral inductor for RF-IC applications with inductance of less than 100 nH on a single-layer design. For the application of HPNA (Home Phoneline Networking Alliance) or RF-telecom designs, which need inductances of more than 10 μH, no published paper or report accurately calculates spiral inductors with a large value in multiple layers.

Three options exist for designing large planar spiral inductors on a PCB: Increase the number of turns; increase the inner diameter, D_{IN}; or add layers and increase the coupling between multilayers. The first two options occupy more area on the PCB, so the third option is the best way to accommodate a large inductor when there is limited PCB area.

Multilayer planar spiral inductors offer several advantages over other inductors. They have stable inductance, for example, and, if the PCB has a fixed layout, their inductance tolerance is less than 2%. Further, spiral inductors cost less than chip inductors and require a less complex manufacturing process, making them easier to manufacture with low yield loss.

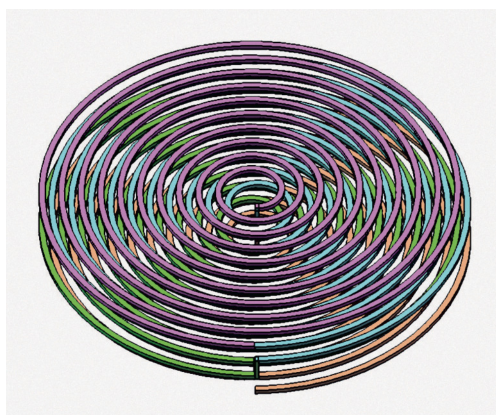


Figure 1 The traditional formula for calculating inductor size is accurate for single-layer planar spiral inductors but does not calculate the inductance of those that employ multiple layers and connect with via holes.

The traditional formula for calculating inductor size is accurate for single-layer planar spiral inductors, but it does not calculate the inductance for planar spiral inductors built on multilayers and connected with via holes (**Figure 1**).

You can calculate a single-layer inductor's value using **Equation 1**:

$$L=[(\mu_0 N^2 D_{AVG} C_1)/2][\ln(C_2/\rho)+C_3\rho+C_4\rho^2)], \qquad (1)$$

where N is the number of turns; μ_0 is the vacuum permeability, $4\pi\times10^{-7}$; ρ is the fill ratio, $(D_{OUT}-D_{IN})/(D_{OUT}+D_{IN})$; D_{AVG} is the average diameter, $(D_{IN}+D_{OUT})/2$; and C_1~C_2 are factors depending on layout (**Table 1**). **Figure 2** defines D_{IN} (inner diameter) and D_{OUT}.

A multilayer inductor creates mutual inductance, however, so 3-D-magnetic-simulation software cannot simulate a multilayer inductor. Even if it could, the process would take a long time, and the results would be inconsistent. Therefore, you must use the following two **equations** for the coupling value, K_C, to obtain the total inductor value with a mutual inductance: $L_{TOTAL}=L_1+L_2\pm2M$, and $M=2\times K_C\times\sqrt{L_1\times L_2}$.

You can obtain another simple and accurate expression for the inductance of a planar spiral by approximating the sides of the spirals using symmetrical current sheets of equivalent current densities (**Reference 1**). Although the accuracy of **Equation 1** decreases as the ratio of space between traces to the trace width increases, it exhibits a maximum error of 8% for a space less than or equal to three times the width. Note that designers typically build practical integrated spiral inductors with space less than or equal to the width because smaller spacing improves the interwinding magnetic coupling and reduces the area the spiral consumes. In PCB design, this practice is not a concern because the intertrace spacing is normally less than the trace width.

Analysis of these **equations** and experimenting with large inductors shows that **Equation 1** is accurate, and the increasing value of the inductor does not affect the accuracy of these **equations**. The result shows an inductance close to the calculated value, with the difference at high frequency due to the actual distribution of parameters throughout the circuit rather than the lumped-parameter analysis of the model (**Figure 3**). Thus, you can use **Equation 1** to calculate a large, single-layer inductor.

Calculations for a multilayer coupled planar spiral inductor are more complex than those for a single-layer spiral inductor.

TABLE 1 LAYOUT-DEPENDENT COEFFICIENTS

Layout	C_1	C_2	C_3	C_4
Square	1.27	2.07	0.18	0.13
Hexagonal	1.09	2.23	0	0.17
Octagonal	1.07	2.29	0	0.19
Circle	1	2.46	0	0.2

TABLE 2 INDUCTOR TURNS

A	B	C	D
0.184	–0.525	1.038	1.001

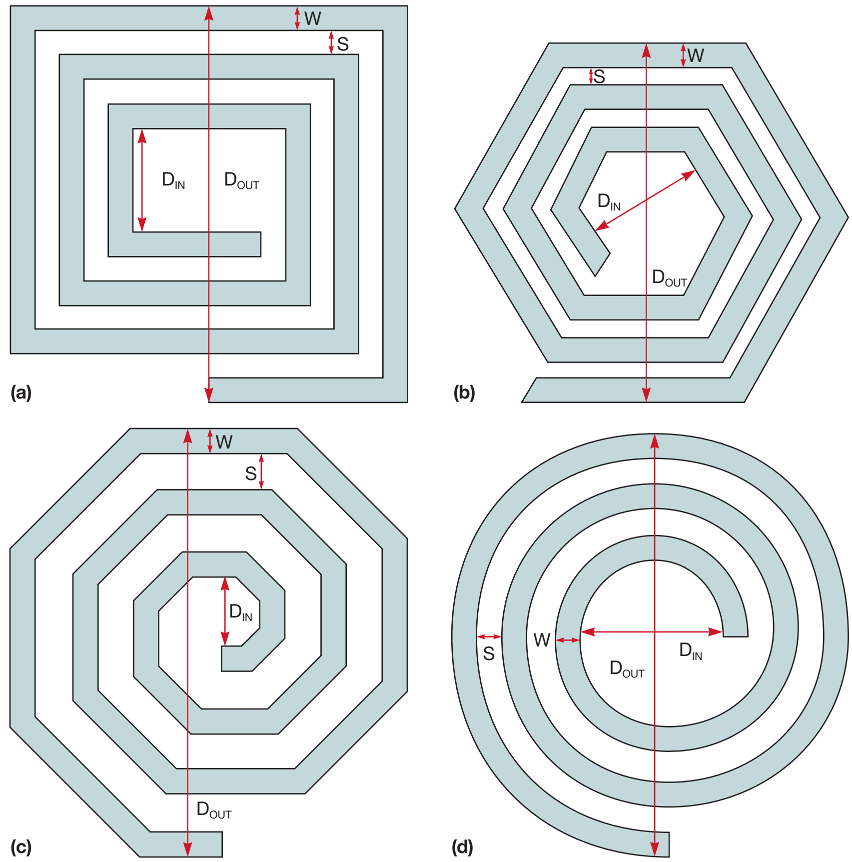


Figure 2 The C_1~C_4 factors depend on layout: square (a), hexagonal (b), octagonal (c), and circle (d).

The coupling between the inductors on each layer is difficult to simulate because the coupling value depends on the number of turns of the inductor and the distance between the two layers. Experimenting over the range of inductor turns, N, with N equal to a 5- to 20-turns ratio, and the distance between the inductors on the two layers, X, with X equal to a 0.75- to 2-mm distance, yields **Equation 2** to calculate the coupling factor:

$$K_C=[N^2/(AX^3+BX^2+CX+D)\times(1.67N^2-5.84N+65)\times0.64], \qquad (2)$$

where X is the distance in millimeters between the inductors on the two layers and N is the number of inductor turns that **Figure 2** defines. The inductor turns of both layers must be the same (**Table 2**).

With the coupling factor from **Equation 2** and the single planar-spiral-inductor calculation from **Equation 1**, you can figure the total inductance of a two-layer inductor by using the mutual-inductance formula (**Reference 2**).

On a two-layer coupled inductor, you can calculate the total inductance with the following layout information: 15.75 turns, 0.127-mm (5-mil) width and trace spacing, 1.0922-mm (43-mil) D_{IN}, and 0.75-mm interlayer distance. First, you must analyze the circular layout to find D_{OUT} and D_{AVG} to obtain the single-layer inductance, L_S, and the coupling factor, K_C: $D_{OUT}=D_{IN}+2\times W+(W+S)\times(2N-1)=8.9972$; $D_{AVG}=(D_{IN}+D_{OUT})/2=5.0927$; $\rho=(D_{IN}+D_{OUT})/(D_{OUT}+D_{IN})=0.7855$; $L_S=[(\mu N^2D_{AVG}C_1)/2]$

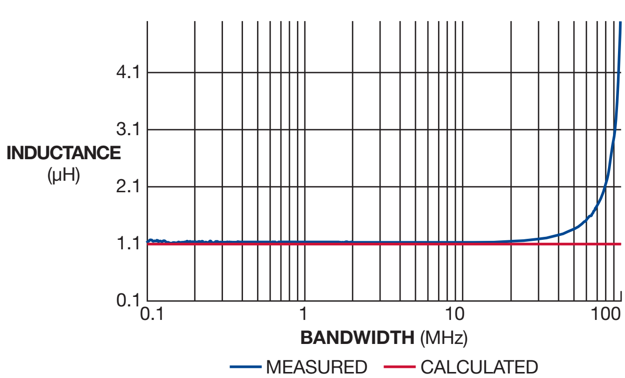
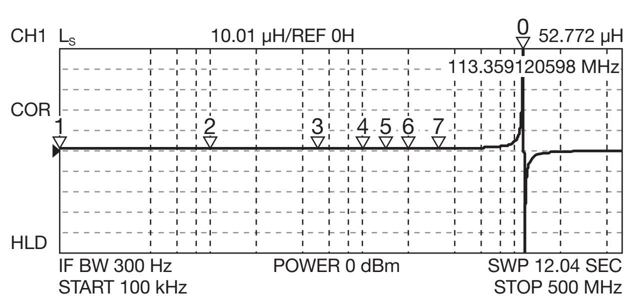


Figure 3 An analysis of the equations shows an inductance close to the calculated value.



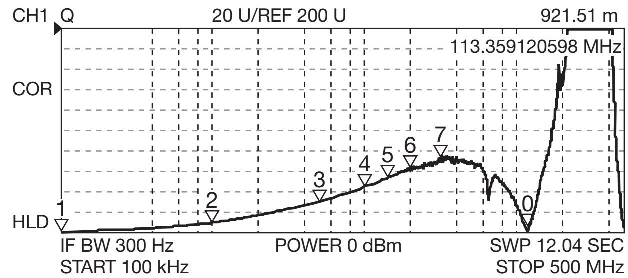
NO.	FREQUENCY	VALUE
0	113.359120598 MHz	52.772 μH
1	100 kHz	1.1618 μH
2	1 MHz	1.1197 μH
3	5 MHz	1.108 μH
4	10 MHz	1.1071 μH
5	15 MHz	1.1137 μH
6	20 MHz	1.1267 μH
7	30 MHz	1.1703 μH

Figure 4 The measured inductor's frequency response is close to the theoretical calculation to a frequency as high as 100 MHz.

TABLE 3 FOUR-LAYER-STACK STRUCTURE			
Layer 1	Spiral inductor	1 mil	0.025 mm
Layer 2	Substrate	34 mils	0.85 mm
	Spiral inductor	1 mil	0.025 mm
Layer 3	Substrate	34 mils	0.85 mm
	Spiral inductor	1 mil	0.025 mm
Layer 4	Substrate	34 mils	0.85 mm
	Spiral inductor	1 mil	0.025 mm

$(\ln(C_2/\rho)+C_3\rho+C_4\rho^2)]=10^{-6}H=1\ \mu H$; $K_C=0.64$. Per the mutual-inductance connection **equations**, the total inductance is $L_1+L_2+2\times K_C\times=\sqrt{L_1\times L_2}=3.28\ \mu H$.

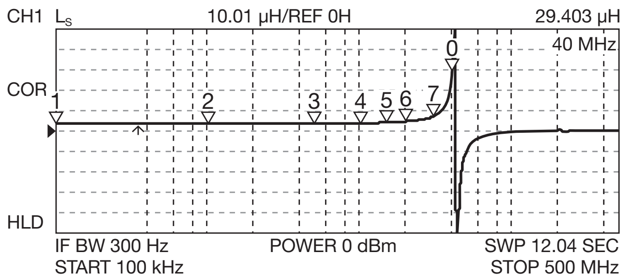
In a design with more than two layers, there are more coupling factors between any two layers. You can use the same method to obtain each coupling factor and then use the total inductance per the mutual-inductance connection formulas. You can also calculate a four-layer spiral inductor with 15.75 turns, a 5-mil-wide trace, a 5-mil trace spacing, and a 43-mil circular inner diameter. **Table 3** shows the stack structure of the PCB. You must first calculate the single-layer inductance, L_S, which is 1 μH. It has six coupling factors: K_{C12}, K_{C13}, K_{C14}, K_{C23}, K_{C24}, and K_{C34}. $K_{C12}=K_{C23}=K_{C34}=0.618$, $K_{C13}=K_{C24}=0.459$, and $K_{C14}=0.294$. So the total inductance is: $L_1+L_2+L_3+L_4+(2\times K_{C12}+2\times K_{C13}+2\times K_{C14}+2\times K_{C23}+2\times K_{C24}+2\times K_{C34})\times L_1=10.132\ \mu H$. The four-layer inductor has a 10.1-μH inductance.



NO.	FREQUENCY	VALUE
0	113.359120598 MHz	921.51 m
1	100 kHz	1.1373 m
2	1 MHz	10.032 m
3	5 MHz	31.196 m
4	10 MHz	45.67 m
5	15 MHz	55.195 m
6	20 MHz	61.729 m
7	30 MHz	71.491 m

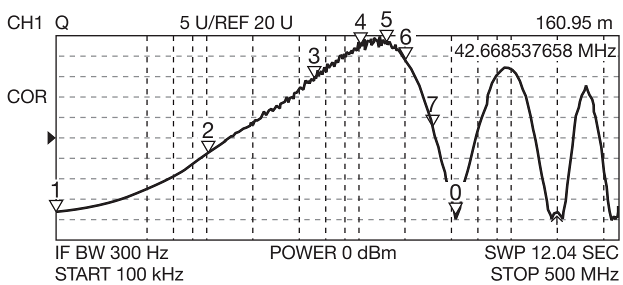
Figure 5 The self-resonant frequency is better than that of a chip inductor with the same value.

Several samples with different sizes and structures verify the new calculation and measure and compare samples. To perform the verification, you must first increase the size of the single-layer planar inductor and then increase the number of turns from four or five to 15. You must also increase the track width from 4 to 200 microns and increase D_{IN} from 100 to 2400 microns. The inductance calculated using **Equation 1** is 1.1 μH. **Figure 4** shows the measured inductor frequency



NO.	FREQUENCY	VALUE
0	40 MHz	29.403 μH
1	100 kHz	3.8144 μH
2	1 MHz	3.7903 μH
3	5 MHz	3.7677 μH
4	10 MHz	3.8956 μH
5	15 MHz	4.1822 μH
6	20 MHz	4.6846 μH
7	30 MHz	7.1989 μH

Figure 6 The frequency response for the spiral inductor is better than that of a chip inductor with the same value.



NO.	FREQUENCY	VALUE
0	42.668537658 MHz	160.95 m
1	100 kHz	2.0236 m
2	1 MHz	16.411 m
3	5 MHz	34.595 m
4	10 MHz	42.162 m
5	15 MHz	42.886 m
6	20 MHz	38.899 m
7	30 MHz	22.878 m

Figure 7 Two-layer planar spiral inductors have better Q and self-resonant frequency than does a chip inductor.

response, which is close to the theoretical calculation to a frequency as high as 100 MHz. The Q value and self-resonant frequency in **figures 4** and **5** are better than that of the same-value chip inductor. Normally, the chip inductor's Q value is only 15 to 20.

To verify the coupling factor, you build two equally sized, 1.1-μH planar spiral inductors on a two-layer PCB substrate with a thickness of 0.8 mm. The calculated inductor value using **Equation 2** is 3.8 μH. **Figures 6** and **7** show the frequency response. The two-layer planar spiral inductor's Q and self-resonant frequency are better than that of a chip inductor with the same value.

Figure 8 shows a fifth-order lowpass filter with two-layer coupled planar spiral inductors using the new calculation for the design of this filter. The performance of the filter matches the simulation result and works for HPNA and other telecommunication applications (**Figure 9**). The simplicity and robustness of these calculations simplify circuit design and optimization applications, which you can incorporate into the computer-circuit model for spiral inductors. EDN

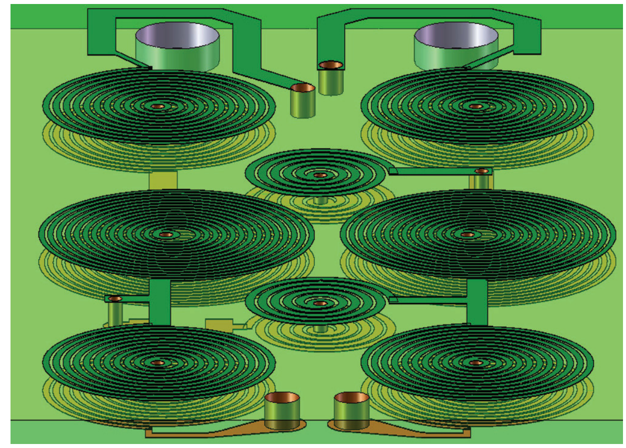


Figure 8 You can build a fifth-order, lowpass filter with a two-layer, coupled spiral inductor.

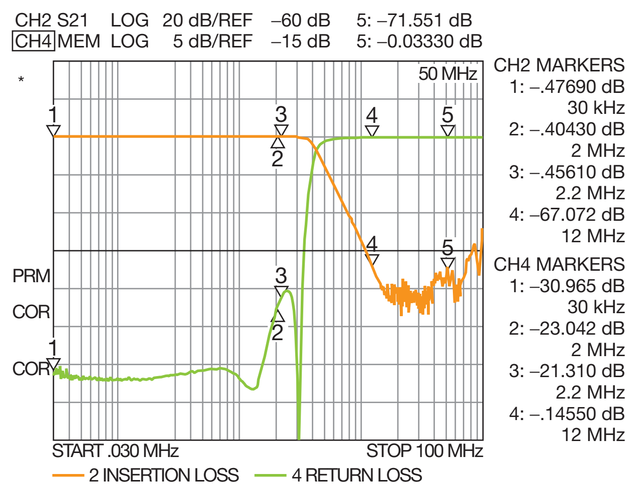


Figure 9 The performance of the filter matches the simulation result.

ACKNOWLEDGMENT

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REFERENCES

1. Rosa, Edward B, "Calculation of the self-inductances of single-layer coils," *Bulletin of the Bureau of Standards*, Volume 2, No. 2, 1906, pg 161, http://bit.ly/9YpeeX.
2. Nilsson, James W, and Susan A Riedel, *Electric Circuits*, Seventh Edition, Prentice Hall, May 17, 2004, ISBN 0131465929.

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AND FRAN GRANVILLE

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READERS SOLVE DESIGN PROBLEMS

Methods measure power electronics' efficiency

Liping Zheng, Calnetix, Yorba Linda, CA

Validating the sytem efficiency of a power-electronics circuit is essential in evaluating the overall system performance, design optimization, and sizing of cooling systems. **Figure 1** shows the conventional method of performing efficiency measurement. The power-electronics system operates at the rated output-power level, and, by measuring the input power and output power, you can calculate the system's efficiency using the **equation** $\eta=(P_{OUT}/P_{IN})\times 100\%$, where P_{OUT} is output power and P_{IN} is input power. In other words, the measured input power is equal to the output power plus the power loss of the system.

However, measuring the efficiency of a high-power system that delivers power to loads such as motors, generators, or industrial-computer equipment requires a source that delivers the rated power. The infrastructue therefore should comprise a suitably rated source and an equivalent load that can support the rating of the power-electronics system you are evaluating. These requirements can drive up the facility's infrastructure cost; for one-time design-validation measurements, this cost is difficult to justify.

This Design Idea describes alternative methods of measuring the efficiency of a high-power power-electronics system that simplifies the test-infrastructure requirement by eliminating the test load and using a source that must support only the loss of the power-electronics system. **Figure 2** shows the proposed method, which eliminates the test load by shorting the output/load terminals. The system's control algorithm maintains the required input- and output-current amplitude and frequency by developing circulating reactive power. IGBTs (insulated-gate bipolar transistors) and magnetic components dominate the system's losses, which are functions of the amplitude and frequency of the input and output currents. The loss is also less sensitive to the power-factor and PWM (pulse-width-modulation) index.

To know the required input and output current, you must estimate the system's power factor, the motor's back EMF (electromotive force), and the systems's source voltage. This example uses a field-oriented control for both source- and load-side inverters, resulting in the following **equations**:

$$I_{ROUT}=I_{ROUT\_RE}+jI_{ROUT\_IM}=\frac{P_{OUT}}{\sqrt{3}V_{BEMF}};$$

$$I_{RIN}=I_{RIN\_RE}+jI_{RIN\_IM}=$$

$$\frac{P_{RIN}}{\sqrt{3}V_{GRID}}=\frac{P_{OUT}/\eta_E}{\sqrt{3}V_{GRID}},$$

where I_{ROUT} is the required output current, which comprises real current, I_{ROUT_RE}, and reactive current, I_{ROUT_IM}; I_{RIN} is the required input current, which comprises the real current, I_{IN_RE}, and the reactive current, I_{IN_IM}; P_{RIN} is the

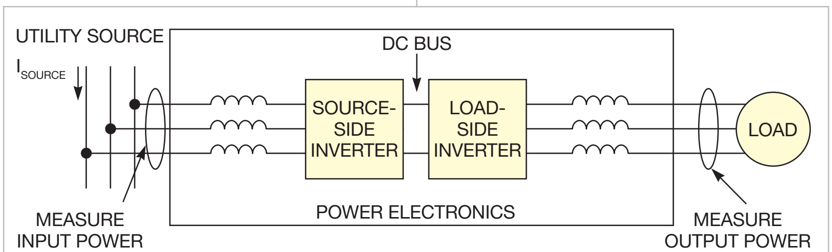

Figure 1 In a conventional method of performing efficiency measurement, the power-electronics system operates at the rated output-power level.

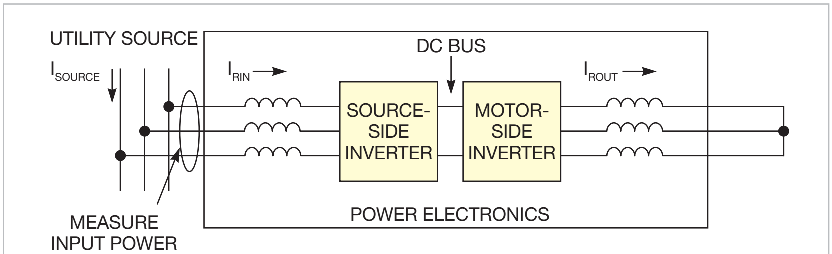

Figure 2 This method eliminates the test load by shorting the output-load terminals.

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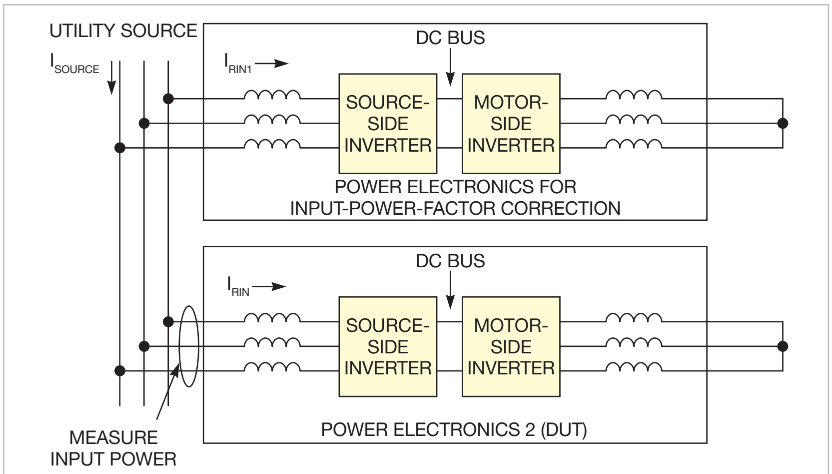


Figure 3 This method uses two identical power-electronics systems. The second system offsets the input reactive current that the test system creates.

required input power; P_{OUT} is the output power at the test condition; V_{BEMF} is the motor's back EMF; V_{GRID} is the grid voltage; and η_E is the estimated efficiency of the circuit.

By maintaining the input current to be I_{RIN} and the output current to be I_{ROUT}, the measured input real power will be close to the power loss, P_{LOSS}, at the actual output-power level, P_{OUT}. Therefore, you can calculate the efficiency as follows: $\eta=(P_{OUT})/(P_{OUT}+P_{LOSS})\times100\%$.

If the measured efficiency, which you calculate using this **equation**, does not quite match the estimated efficiency, η_E, update the second **equation** using the measured efficiency, η, and repeat the measurement until they are close. Calnetix (www.calnetix.com) has used this method to evaluate the efficiency of a 125-kW power-electronics system, compared the results with the conventional measurements, and found them to be closely matching.

Most high-power power-electronics systems have high efficiency, which means that the real current is much less than the reactive current. To reduce the required current from the grid, you can use the method in **Figure 3**, which uses another identical system to offset the input reactive current that the test system creates. By providing a path for circulating reactive power, the utility sources the lost power only, not the total power. In **Figure 3**, the input current of the second power-electronics circuit is $I_{RIN}=I_{RIN\_RE}+jI_{RIN\_IM}$. By setting the first circuit to have an input current of $I_{RIN1}\approx I_{RIN\_RE}-jI_{RIN\_IM}$, the power from the source is only $I_{SOURCE}=I_{RIN1}+I_{RIN}\approx I_{RIN\_RE}+I_{RIN\_RE}+j(I_{RIN\_IM}-I_{RIN\_IM})=2I_{RIN\_RE}$. The circuit uses the input current from the source only to overcome the power losses of the two circuits, thereby eliminating the need for a high-power infrastructure. EDN

Circuit extends battery life

José M Espí, Rafael García-Gil, and Jaime Castelló,
University of Valencia, Valencia, Spain

Two previous Design Ideas describe simple ways to automatically disconnect a battery from its load after a preset on period, which extends battery life (**references 1** and **2**). These circuits have little loss in standby operation, but they do draw some current. The circuit in this Design Idea presents a simpler way to perform the same function with fewer components and with no power consumption during standby operation (**Figure 1**). Moreover, the network comprising R_2, D_2, and C_2 activates and deactivates the circuit. An additional control signal, control on/off, becomes slower than the battery's on/off cycle.

Switching S_1 to Position 1, the on position, the 24V battery quickly charges capacitor C_1 through diode D_1. That voltage drives transistor Q_1 into saturation. Q_1's saturation magnetizes and activates relay coil L_1, connecting the battery to the main power and control board. Meanwhile, capacitor C_2 charges more slowly through 100-kΩ resistor R_2, thus generating the control on/off signal with some delay relative to the relay coil's closing. That scenario occurs after

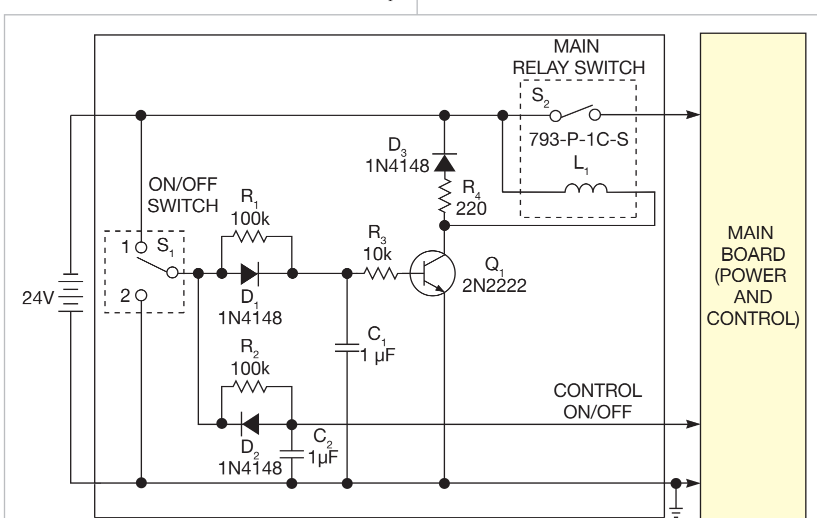
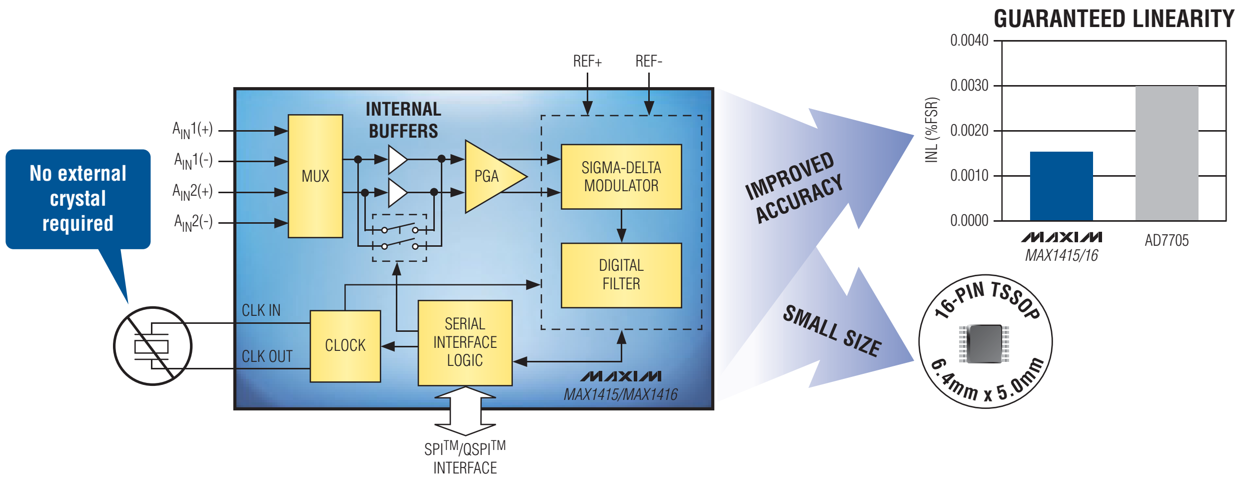


Figure 1 This on/off management circuit uses a relay to remove battery power.

Pin-compatible upgrades to AD7705 improve accuracy

Lower cost by eliminating external crystal



- **Drop-in replacement for AD7705 achieving 200% accuracy improvement**
- **Lower BOM cost by eliminating external crystal (MAX1415/16)**
- **Built-in programmable gain amplifier (PGA) improves measurement for small signals**

Part	Resolution (Bits)	Channels	Update Rate (ksps)	Supply Voltage (V)	INL (%FSR)	Clock	Pin-Package	Price† ($)
MAX1415	16	2	0.5	2.7 to 3.6	0.0015	Int/ext	16-TSSOP/PDIP/SO	3.45
MAX1416*	16	2	0.5	4.75 to 5.25	0.0015	Int/ext	16-TSSOP/PDIP/SO	3.45
MX7705	16	2	0.5	2.7 to 5.25	0.0030	Ext crystal	16-TSSOP/PDIP/SO	2.95
MAX1400/01	18	5	4.8	4.75 to 5.25/2.7 to 3.6	0.0015	Ext crystal	28-SSOP	8.95
MAX1402/03	18	5	4.8	4.75 to 5.25/2.7 to 3.6	0.0015	Ext crystal	28-SSOP	8.95

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the proper power supply to the power stage and control circuits.

Switching S_1 to Position 2, the off position, causes capacitor C_1 to slowly discharge through resistor R_1 when diode D_1 is off. That action delays Q_1's turn-off. Before Q_1 turns off, C_2 quickly discharges through D_2, indicating that the control should shut down the power. The relay switches off with minimum current. Once Q_1 is off, the relay coil demagnetizes through R_4 and D_3. The relay switches off, disconnecting the main power and control board from the battery. During this off state, current flows neither in the on/off circuit of the management board nor to the main board. **EDN**

REFERENCES

1 Gimenez, Miguel, "Scheme provides automatic power-off for batteries," *EDN*, May 13, 2004, pg 92, http://bit.ly/aUdD3s.

2 Xia, Yongping, "Battery automatic power-off has simpler design," *EDN*, March 31, 2005, pg 80, http://bit.ly/bLJNgb.

Pulse generator corrects itself

Marián Štofka, Slovak University of Technology, Bratislava, Slovakia

Using a shift register with parallel output is a common way to design a pulse generator with N inputs and pulsed outputs having a width of T/N. To keep the output pulses consecutive, you can use feedback from the last output to the first input. At power-on, such a circuit can have a random combination of logic zeros and ones, forming an undesired data content of the shift register. To avoid circulating undesired states and to enter a proper sequence, you need a special feedback.

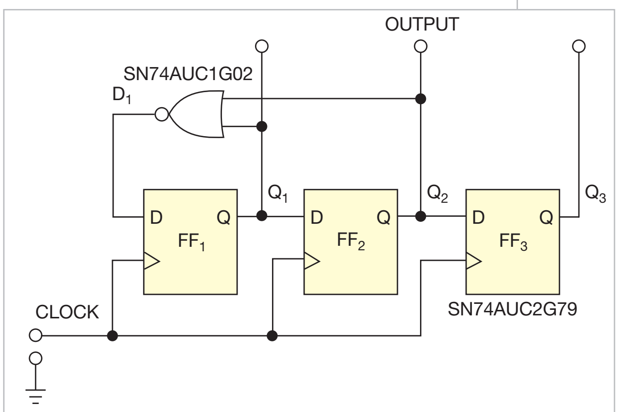

Figure 1 This one-of-three pulse generator uses three ICs, yet it avoids false logic states.

The circuit in **Figure 1** is a three-stage shift register that uses D-type flip-flops. It has three outputs, Q_1, Q_2, and Q_3, each of which produces a periodic pulse having a width of $T_{REP}/3$. $T_{REP}=3T_{CLK}$ is the period at which the sequence repeats at any of the three outputs. A two-input NOR gate creates the feedback. The gate's D_1 output connects to the D input of flip-flop FF_1, and its inputs connect to Q_1 and Q_2. A logic-one bit at D_1 means that, at the nearest low-to-high transition of the clock, this signal will place a logic one at output Q_1.

You can interpret this feedback in words by writing a logic zero into FF_1 at the nearest low-to-high transition of the clock signal, if at least one of the Q_1 or Q_2 outputs has a logic-one state. You write a logic one into FF_1 if both the Q_1 and the Q_2 outputs are at logic zero. This feedback adds a self-correcting feature, which is illustrated by the assumption that the initial state of the circuit is intentionally undesired.

Using this result, the following sequences illustrate state correction, in which the logical states in the bit triads correspond left to right to Q_1, Q_2, and Q_3:

111→011→001→100→010→001
000→100→010→001

From this example, you can see that erroneous state 111 self-corrects within two periods of the clock. For the undesired 000 state, the proper cycling enters at the nearest low-to-high transition of the clock signal.

You can determine the upper limit of the clock frequency from an assumption of the gate output, which changes after a low-to-high transition of the clock. This condition must be ready with a setup time, T_{SETUP}, the next time the clock transitions from low to high (**Figure 2**). Thus, $T_{CLKMIN}=T_{PQHL}+T_{PGLH}+T_{SETUP}$, where T_{PQHL} and T_{PGLH} are signal-propagation delays of the flip-flop and the gate, respectively, at the respective output-level transition. By using the worst-case values of propagation delays from the devices' data sheets, you get a minimum clock period of 4.4 nsec for a supply voltage of 1.8V and a minimum clock period of 3.5 nsec for a supply voltage of 2.5V. As the 3.5-nsec value gives a clock frequency higher than the guaranteed toggle frequency for the flip-flop, you should accept the maximum clock frequency at 275 MHz for a supply voltage of 2.5V. For a supply voltage of 1.8V, the maximum clock frequency should be 227 MHz. The maximum repetition rate of signals at Q_1, Q_2, and Q_3 outputs is the maximum clock frequency divided by three, or 75.6 MHz. **EDN**

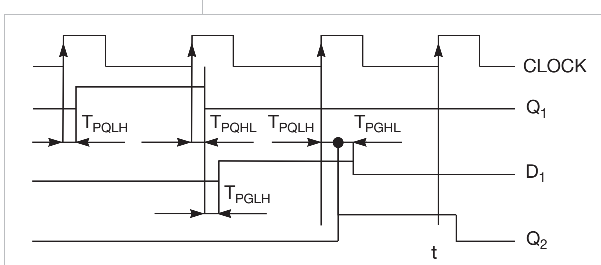

Figure 2 The circuit generates glitch-free logic waveforms that are successive in time and have accurate duty cycles of 33.3%.

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DS28E01**/DS28E02†	3.3V/1.8V, 1Kb EEPROM with SHA-1	1-Wire®	Bidirectional SHA-1 challenge and response
DS28E10†	SHA-1 authenticator	1-Wire	SHA-1 challenge and response
DS2401/DS2411	64-bit ROM serial number	1-Wire	Customized 64-bit ROM
DS2431	1Kb EEPROM	1-Wire	Customized 64-bit ROM, WP/OTP modes
DS2460**	SHA-1 coprocessor	I^2C	Secure storage of system secrets

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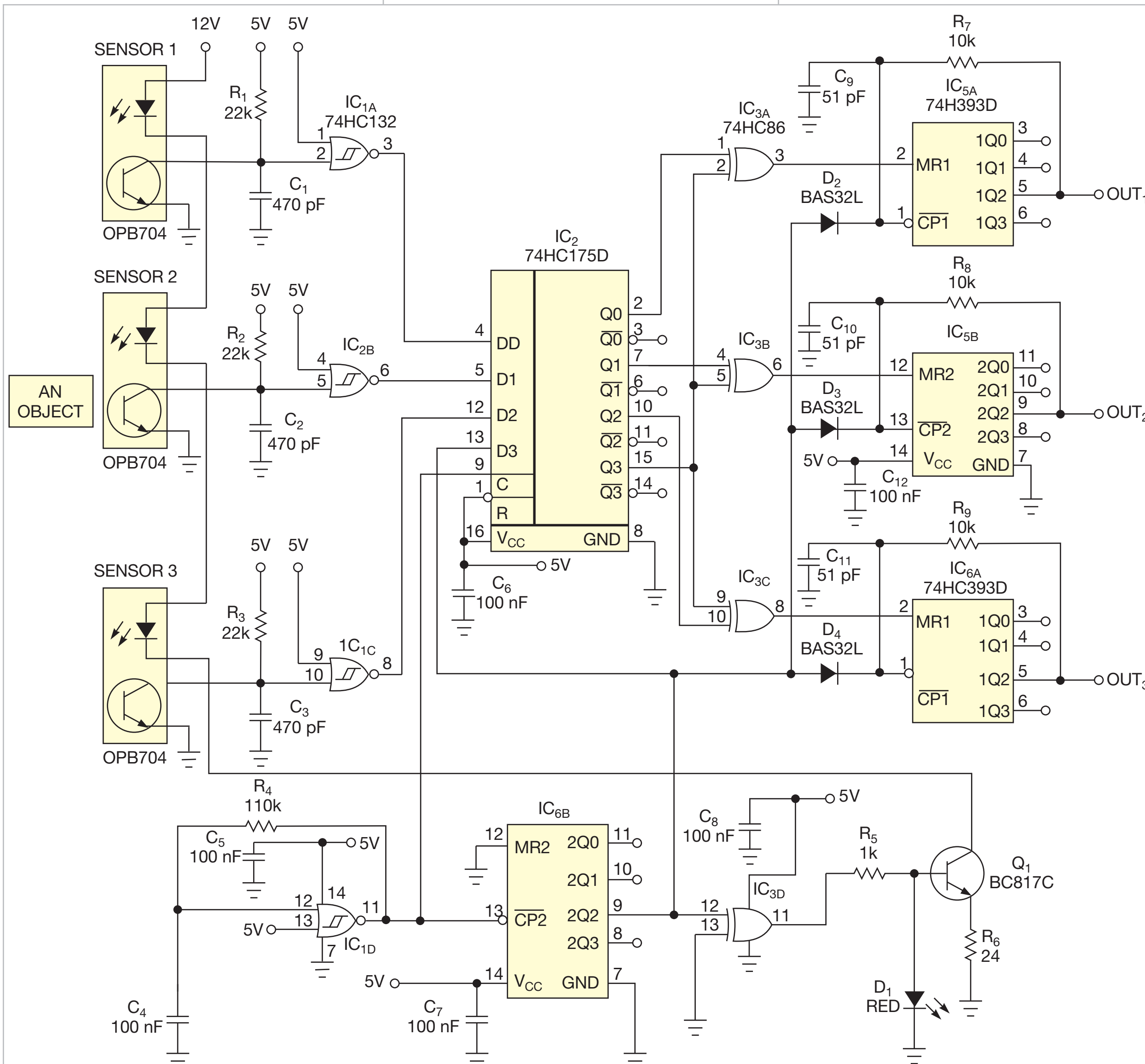
Reflective object sensor works in bright areas

Vladimir Rentyuk, Modul-98 Ltd, Zaporozhye, Ukraine

When using a reflective object sensor, counting and identifying objects is sometimes difficult in the presence of electrical noise or bright ambient light. The circuit in **Figure 1** shows an inexpensive solution to this problem using three independent and simultaneously working reflective object sensors. The circuit is suitable for many types of objects, but it targets use with objects such as cards.

The circuit uses three OPB704 reflective optical sensors with Schmitt-trigger NAND comparators IC_{1A}, IC_{1B}, and IC_{1C} on each output. IC_{1D} functions as a clock generator, and counter IC_{6B} functions as a divide-by-eight counter that divides the clock frequency. That signal drives IC_{4D}, which acts as a buffer to drive transistor Q_1.

To understand how the circuit works, consider Sensor 2. IC_{1B}'s output will be low if the sensor's phototransistor doesn't detect IR rays reflected from an object. Both of IC_{1B}'s inputs are high; therefore, the D1 input of IC_2 is low. In any case, if the sensor's phototransistor detects IR rays reflected from an object, the D1 input of IC_2 is high. The level corresponding to the current situation transfers through IC_2's Q_1 output (Pin 7) by a write signal on the C input (Pin 9). The write signal is a leading edge of puls-



NOTE: LOW-VOLTAGE LEVEL OCCURS WHEN NO OBJECT IS PRESENT; HIGH-VOLTAGE LEVEL OCCURS WHEN THE OBJECT IS PRESENT.

Figure 1 Infrared sensors and logic circuits detect the presence of an object.

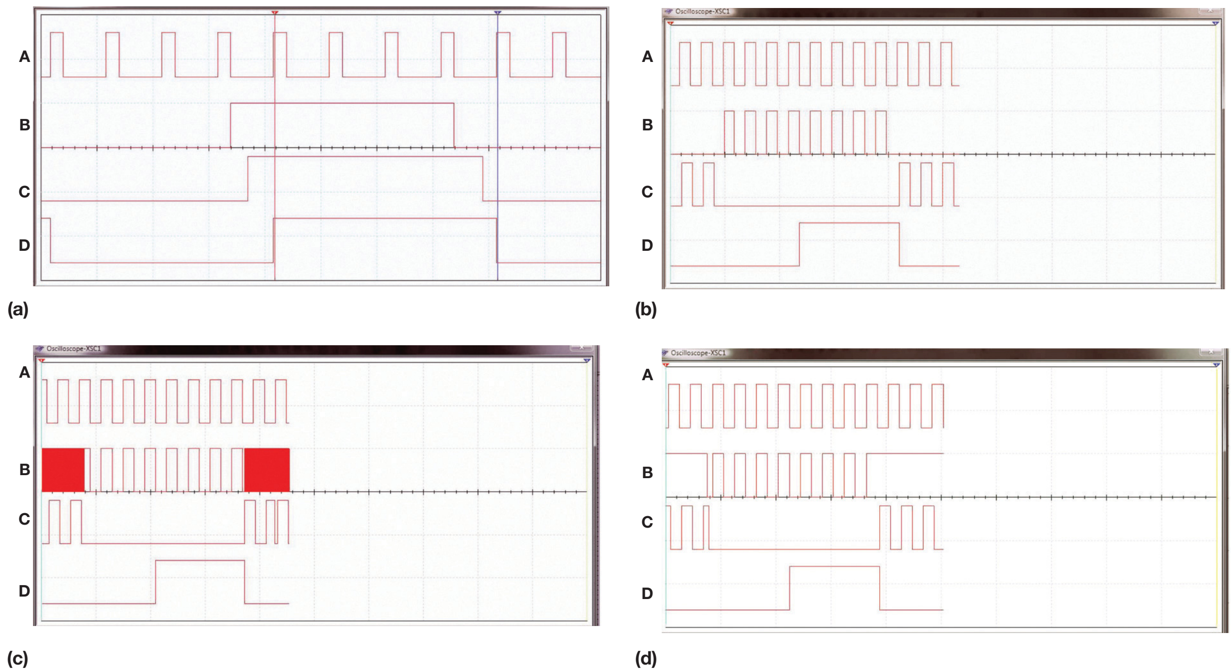


Figure 2 Traces show the process of normalization (a) and three cases of using the presented device (b, c, and d).

es from the clock generator. The signal from divider IC_{6B} becomes the D3 input of IC_2. A level of the divided clock signal transfers to IC_2's Q3 output (Pin 15) upon receiving a write signal from the C input (Pin 9). The signals on the Q1 and Q3 outputs have equal duration except when the sensor's phototransistor detects IR rays reflected from an object. **Figure 2a** shows the process of this normalization. Exclusive-OR gate IC_{3B} compares the Q1 and Q3 outputs from IC_2. If they have the same logic level and duration, then IC_{3B}'s Pin 6 is low, and IC_{3B} generates pulse signals. If signals from outputs Q1 and Q3 on IC_2 are unequal, you must reset counter IC_{5B}'s reset signal, and its output 2Q2 at OUT_2 is low. The Q2 outputs of counters IC_{5A}, IC_{5B}, and IC_{6A} are low whenever the input signals of comparator circuits IC_{3A}, IC_{3B}, and IC_{3C} are unequal. This situation occurs if Sensor 2 doesn't detect an object or receive any external signals—for example, IR noise from fluorescent lamps or interfering ambient light, alternating light, or flashes.

The outputs of IC_{3A}, IC_{3B}, and IC_{3C} are equal only when all phototransistors detect a signal from their respective IR emitting diodes—that is, when a card is presented in front of Sensor 2 (**Figure 2b**). You must choose a clock frequency with regard to a delay time of the system. A leading edge triggers IC_2, a 74HC175, and a falling edge triggers IC_{6B}, a 74HC393. Because of the counters, this system automatically adjusts itself after any changes of frequency in its clock generator. Thus, if counter IC_{5B} does not have a reset signal during a period equal to four periods of a reference signal, its output (Pin 9) is high, and the counter latches through R_8. The logic-high level appears on OUT_2 until you remove the card. In this case, the detected inequality signal from the sensor with the reference signal and the counter, IC_{5B}, causes a reset signal. **Figures 2b**, **2c**, and **2d** show three cases of using the presented device.

Figure 2b shows a case of normal operation. You can see the results of comparing a reference signal (Trace C) and a signal of IC_{1B}'s output (Trace D). The signal of IC_{1B}'s output (Trace B) is low when no card appears. When the card enters the zone of vision of a sensor (Trace B), it is a sequence of normalized pulses. The output of the device at Pin 9 of IC_{5B} (Trace D) changes its level from low to high after four cycles of both signals, but it will immediately change to low if you remove the card.

Figure 2c shows operation of the device under strong IR noise. The signal of IC_{1B}'s output (Trace B) contains some high-frequency signals if a card isn't present and is a sequence of normalized pulses when a card is present. The output of the device at Pin 9 of IC_{5B} (Trace D) indicates the presence of a card by changing its level from low to high after four cycles of these signals. It immediately changes to low if you remove the card from the zone.

Figure 2d shows operation of the device under ambient direct lighting. You can see the results of comparing signals. In this case, the signal at IC_{1B}'s output (Trace B) is constant high when a card isn't present. When the card enters a sensor's zone of vision (Trace B), the signal is a sequence of normalized pulses. The output of the device at Pin 9 of IC_{5B} (Trace D) indicates this condition by changing its level from low to high after four cycles of both signals. It immediately changes from high to low when you remove the card from the zone.

Capacitors C_1, C_2, and C_3 are optional. They protect input circuits from electromagnetic noise when, for example, long wires connect the sensors and the device. Capacitors C_9, C_{10}, and C_{11} provide performance reliability by protecting the counters from short pulses. EDN

productroundup

PASSIVES

Heavy-duty capacitors offer capacitance values as high as 2235 μF

The HDMKP series of capacitors is available in voltages of 900 to 2700V dc and offers capacitance values as high as 2235 μF, with a capacitance tolerance of ±5%. The devices target use in dc and ac filtering and dc-linking applications in power converters for interruptible power supplies, wind turbines, and power converters for traction and industrial devices. The metallized-film capacitors feature current ratings as high as 150A, impulse current as high as 25 kA, and self-inductance of less than 70 nH. Capacitor-height options range from 105 to 260 mm, and diameters are 84.4 and 116 mm. The devices feature a nonpolar dielectric and use an integrated M 12 stud on their base for mounting. Operating temperature ranges from −40 to +70°C at full rated voltage or as high as 100°C at half the rated voltage. Prices start at $43.75 (50) each.
Vishay Intertechnology Inc, www.vishay.com

Chip resistor has high stability, low resistance

The LRF3W-MIL series of chip resistors uses high-reliability, thick-film

materials and is available with screening that meets the MIL-PRF-55432 military standard. Resistance ranges from 0.003 to 1Ω, with a rated power of 3W at 70°C. Absolute temperature coefficients of resistance are ±100, ±250, and ±500 ppm/°C, and absolute tolerances are ±1, ±2, ±5, and ±10%. Operating temperature ranges from −55 to +150°C. Typical prices start at $2.50 (500).
TT Electronics IRC, www.irctt.com

Resistor offers high load life and short overload stability

The MRS version of the vendor's MR series of low-value molded resistors has a molded axial leaded construction, yielding high load life and time-overload stability that is twice that of its MR predecessor. The devices target use in sensitive power-control circuitry that

demands a minimal shift in resistance. Price for the 2W version of the resistor is approximately 35 cents each.
Stackpole Electronics Inc, www.seielect.com

Integrated baluns convert signals for Bluetooth transceivers

Occupying as much as 70% less PCB area than traditional baluns with discrete components, the BAL-2593D5U and BAL2690-D3U integrated baluns

convert the antenna signal to a balanced pair of signals, which Bluetooth transceivers require. The BAL-2593-D5U targets use with the stand-alone STLC2500D Bluetooth transceiver and STLC2592/3 combo devices, which implement an FM-radio tuner, enabling users to listen to radio directly on a Bluetooth headset. The BAL-2690D3C partners with the STLC2690 to provide

a Bluetooth/FM-tuner combo that also adds a short-range FM transistor, allowing users to play stored music through a system such as a car radio. The BAL-2593D5U comes in a 1.16×1.26-mm footprint with a less-than-0.7-mm profile and has 1.2-dB insertion loss. The BAL-2690D3U comes in a 0.91×0.91-mm footprint with a less-than-0.7-mm profile and has 0.8-dB insertion loss. Available in four-bump flip-chip packages, the devices sell for 25 cents (5000) each.

STMicroelectronics,
www.st.com

High-power molded inductor targets use in harsh environments

Targeting use in servers, notebooks, workstations, dc/dc converters, point-of-load modules, telecom and datacom equipment, and LED-lighting drivers, the HM72B series of surface-mount power inductors measures 6.8×7.23 mm and has a maximum board height of 3 mm. The unit's design uses a pressed powdered-alloy iron core, allowing it to withstand harsh environmental elements. Typical inductance values range from 0.1 to 33 μH. Heating current ranges from 1.8 to 26.2A dc, and saturation levels range from 3.5 to 60A dc. Operating-temperature ranges from −40 to +155°C, with a maximum temperature-rise rating of 50°C. Typical dc resistance ranges from 1.5 to 302 mΩ. Typical prices range from 55 to 59 cents (10,000).

BI Technologies,
www.bitechnologies.com/products/magnetics_list.htm

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It's what's inside that counts

DANIEL VASCONCELLOS

Nine years ago, I was working at a company dealing with light-curing systems. The cornerstone of the business was a UV (ultraviolet)/visible spot-curing unit that could withstand the mechanical and electromagnetic disturbances common in a manufacturing environment. It was well-received in the medical, optoelectronics, and electronic-assembly markets. However, the box buried some performance issues.

The heart of the system was a high-pressure, 100W, mercury-vapor short-arc lamp. Its major disadvantage was deteriorating output: At the end of the typical lifetime of 2000 hours, light intensity was less than 60% of its initial value. The instrument had two major approaches for coping with the issue. The first approach used a built-in radiometer to monitor light intensity, and a microcontroller adjusted an iris opening to ensure that output was within 5% of the set value. The second approach was to use the microcontroller to increase the accuracy of the "dose"—the light intensity times the exposure time. An accurate dose was important for a strong bond. Beyond these requirements, customers regularly performed calibration using the system's built-in radiometer, and our staff normally used a handheld radiometer for preshipment calibration.

The problem arose when a customer bought both a spot-curing system and a handheld radiometer. He plugged the light guide of the curing unit into the calibration port of the built-in radiometer and then into the handheld radiometer and found significant discrepancy in readings. He also complained that readings on the spot-curing display were changing in large steps even at small changes of desired intensity.

It turned out that many things needed improvement. The troubles started with the built-in radiometer. It showed linear response; however, the calibration procedure required only a slope calibration. The radiometer also did not allow for autozero and autoranging adjustment despite the fact that the board had a trimming potentiometer for that purpose.

The second problem was the microcontroller, an Intel 80C196. Although it was a powerful unit, its built-in ADC's resolution was only 10 bits, and absolute error and nonlinearity were ±3 LSB (least-significant bit) each. The ADC displayed numbers from 0 to 25,000 mW/cm^2 but provided a minimum display step of only 25 units. The ADC and the controller sections shared a 5.14V power supply, although the firmware assumed a value of 5V.

There was also a 5- to 6-mV drop between the grounds of the internal radiometer and the ADC, contributing one more bit of inaccuracy to the analog-to-digital conversion. In contrast, the handheld radiometer had a 12-bit ADC with maximum error of ½ LSB.

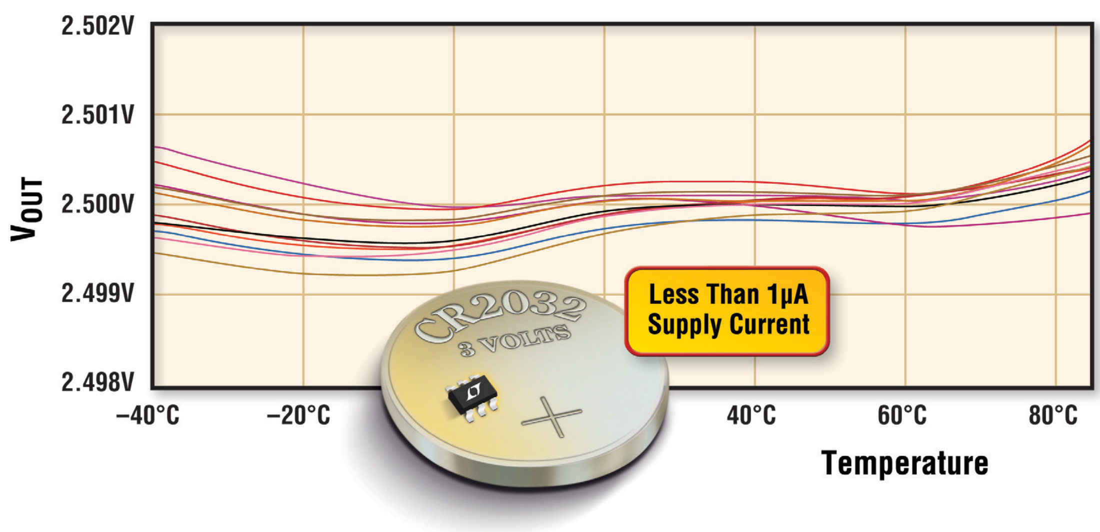
After several hard days and sleepless nights working on a solution, I prescribed two-point calibration for the built-in radiometer, rearranging wiring between the radiometer and the controller boards, using two of the free ADC inputs and corresponding firmware to implement autozero and autoranging for the ADC, and introducing a ground layer for the controller board. I left the low-resolution display as it was. The only way to fix it would have been to use a high-quality external ADC, but I lacked the resources for this approach. Even without this fix, the 5% error threshold dropped from 5.14 to 0.33 W/cm^2.

I heard later that one engineer had designed both the hardware and the firmware of the instrument. With limited time, he hadn't had the chance to verify performance and fix problems. Years later, we had to do it in even less time to meet the deadline.

This experience reminded me of two lessons: When designing an instrument, thoroughly do your homework. When buying an instrument, remember that appearance is important but what really counts is what's inside the box. EDN

Jordan Dimitrov is an electrical engineer from Toronto, ON, Canada.

1µA Precision Reference 10ppm/°C Maximum Drift



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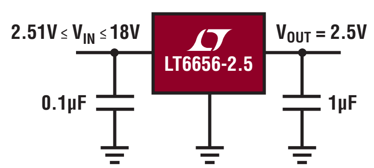
Features

- 1µA Maximum Supply Current
- Excellent Accuracy:
  - A-Grade: 0.05% Max
  - B-Grade: 0.1% Max
- Low Drift:
  - A-Grade: 10ppm/°C Max
  - B-Grade: 20ppm/°C Max
- 5mA Output Drive Capability
- Reverse Input / Output Protection
- 3mV Dropout Voltage
- Thermal Hysteresis: 25ppm
- Fully Specified Over –40°C to 85°C
- Operational from –55°C to 125°C
- Voltage Options: 1.25V, 2.048V, 2.5V, 3V, 3.3V, 4.096V & 5V
- Low Profile (1mm) ThinSOT™ Package

2.5V Reference



Actual Circuit

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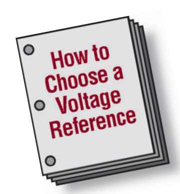

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